# FROM
# NEBULA TO NEBULA

GEORGE HENRY LEPPER

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# FROM
# NEBULA TO NEBULA

OR

## THE DYNAMICS OF THE HEAVENS

Containing

A BROAD OUTLINE OF THE HISTORY OF ASTRONOMY
A GENERAL SUMMARY OF ITS ACHIEVEMENTS
A SYNOPSIS AND CRITICISM OF RECENT
COSMOLOGICAL THEORIES

AND

especially

AN EXPANSION OF THE PRINCIPLE OF UNIVERSAL
GRAVITATION TO THE SOLUTION OF MANY
COSMIC PROBLEMS HERETOFORE DEEMED
INSOLUBLE

BY

GEORGE HENRY LEPPER

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# I

# GENERAL INTRODUCTION

THE object of this work is twofold: first, to present a re-valuation of the time-honored doctrines upon which modern astronomical science is based, and, secondly, to propose a new system of cosmology revealing the entire universe in the philosophic aspect of a single organic unit. Like that of Newton, my system is founded upon the great underlying principle of universal gravitation; but it improves upon his by taking into account the hitherto unexploited factor of the joint attraction of the stars and its dynamical influence upon the domestic relations of our solar family.

During the two centuries which have elapsed since the publication of *The Principia* many important astronomical facts have come to light, for example; the journey of the sun in space, the proper motions of stars, the enormous age of the earth, the anomalous acceleration of the moon, the existence of nebulæ, etc., whose successful incorporation into gravitational astronomy demands, not adaptation merely, but radical reconstruction.

Astronomers in general appear to have lulled themselves into the comforting belief that the paramount problems of astronomy have been successfully disposed of, and that little remains to be done save detail work, such as, the classifying of star spectra, keeping tab on the variable stars, computing asteroidal orbits, and the like, —a romance which popular writers on astronomy have long been busily disseminating among their lay readers.

Let us inquire, then, what progress science has really made toward solving some of these

### *PARAMOUNT ASTRONOMICAL PROBLEMS*

1. *The Origin and Maintenance of Celestial Motions.*
2. *The Law of Gravitation.*
3. *The Source of the Sun's Heat.*
4. *The Genesis of the Solar System.*
5. *The Origin and Nature of Comets.*
6. *The Causes of the Tides.*
7. *The Individual Characteristics of the Planets.*
8. *Stellar Problems in General.*
9. *The Destiny of the Universe.*

### CELESTIAL MOTIONS

Newton, in common with his backward age, believed implicitly in the Mosaic cosmogony, namely, that only six millenniums before him Jehovah had created the heavens and the earth and, as part of the creative plan, launched the moon in her orbit around the earth and the planets in their orbits around the sun. In this way he felt himself absolved from the otherwise logical necessity of assigning definite physical causes for the origin of those motions. A century or so after Newton's death, however, when Geology had proved the immense age of our globe, men's conceptions of nature underwent a great philosophic change. Newton's idea of a personal Creator bowling worlds about began to look altogether too naïve to an agnostic age, and scientists started to cast about for a natural explanation. Such an "explanation" they promptly found; but in naïvete it infinitely surpasses Newton's conception, and might with better propriety have emanated from the brain of Mrs. Stowe's Topsy, who "just growed". This explanation is, forsooth, nothing more or less than the bald assertion that the assumed original rectilinear planetary and stellar motions do not stand in need of explanation at all; that motion is just as "natural" to celestial bodies as rest; that the earth rotates on its axis because it always did so; that the sun, moon, earth, planets, stars, comets, asteroids, meteors and what-not move of themselves without either impulsion or propulsion. If this is seriously to be regarded as a "solution", then every imaginable problem is as good as solved, and fair woman's "just because" rises to the explicitness of a categorical answer. Here is a pertinent quotation drawn from Dr. Charles A. Young's textbook, *General Astronomy,* a standard work taught in most of the universities and colleges of this country (Art. 400):

> It has been customary with some writers to speak of a body thus moving "uniformly in a straight line" as actuated by a "projectile force", a very unfortunate expression, which is a survival of the Artistotelian idea that rest is more "natural" to matter than motion, and that when a body moves, some force must operate to keep it moving. The mere uniform rectilinear motion of a material mass in empty space implies no action of a physical cause, and demands explanation only as mere existence does. Change of motion, either in speed or direction—this alone implies force in operation.

And here is another, to much the same purpose, from the pen of Prof. Frederick Soddy, the celebrated physicist of Glasgow University (*Matter and Energy,* p. 19):

> Before the doctrine of its conservation was established, energy was mysterious and unaccountable in its comings and goings. To-day it is no longer a mystery. The unaccounted-for appearance or disappearance of a quantity of energy in any process, however complex, would rouse as much scientific interest as the mysterious appearance or disappearance of matter. When it appears it must come from somewhere, and when it disappears it must go somewhere. Gradually this Law of Conservation has supplied the physicist with an experimental test of reality in a changing universe. What appears and disappears mysteriously, giving no clue of its origin or destination, is outside of his province. To him it has no physical existence. What is conserved has physical existence, whether it is tangible and ponderable like matter, or intangible and imponderable like energy. Early writers, when they really meant what is now called energy,

often used the term force; and the idea of force, as will later be discussed, has confused the issues and retarded the growth of science to an almost incalculable extent. Carlyle says, meaning energy—"Force, Force, everywhere Force; we ourselves a mysterious Force in the centre of that "There is not a leaf rotting on the highway but has Force in it: how else could it rot?" The very idea of Force is, however, what would be termed an anthropomorphism; that is to say, it ascribes the behavior of inanimate objects to causes derived from the behavior of human beings. We have come to associate the motion of matter with somebody or something pulling or pushing it. When one body is observed to move toward another, like a stone falling to the ground, it has been supposed that, although no agent is visible, something must be pulling it. What, however, is actually observed is a change of position of the body, which acquires at the same time motion or velocity. The observation is correctly expressed by saying that energy, before associated with the position of one body with reference to another (potential energy), has changed into energy of motion (kinetic energy). To suppose that the one body attracts or pulls the other with a certain "force" is to imagine a cause which, if it existed, would account for the effect. *Forces are not conserved, they have no physical existence, but they still survive even in scientific parlance, mainly because of the poverty of the language, which hardly allows effects to be expressed without some causal inference.*

And on his page 112 Mr. Soddy says further:

An ingenious theory of gravitation was put forward a century ago which, though not accepted, is very suggestive, and illustrates the difference between what science would consider a real cause and *one that is fictitious, like the "force of gravity."*

Now, it must not be supposed that these excerpts are merely the unsupported opinions of two eminent men; on the contrary, they express the consensus of opinion of the entire orthodox scientific world. Coldly analyzed, they amount to a denial of the inviolability of natural law, and set a finite limit to the chain of physical cause and effect. To do either of these things is to destroy the very foundation of physical science. A nebula can no more rotate, I hold, without the continued application of some physical power than can a mill-wheel, nor a star spontaneously shoot through space any more than can a leaden bullet. Modern Astronomy is therefore based on a rank heresy. It sets out to solve the machinery of the solar system, first, by inanely assuming that it got started without power, and, secondly, by interpreting its manifold concordances as just happy fortuities. As a very abbreviated list of the host of things about our solar system which astronomers confess their inability to explain, in spite of the aid of these factitious assumptions, let me quote again from Dr. Young's book (*Gen'l Astr.*, p. 566):

> In the present state of science many of the questions thus suggested seem to be hopelessly beyond the reach of investigation, while others appear like problems which time and patient work will solve, and others yet have already received clear and decided answers. In a general way it may be said that the *condensation and aggregation of rarefield masses of matter under the force of gravitation; the conversion into heat of the (potential) "energy of position" destroyed by the process of condensation; the effect of this heat upon the contracting mass itself, and the radiation of energy into space and to surrounding bodies as waves of light and heat*—these principles contain nearly all the explanations that can thus far be given of the present state of the heavenly bodies.
>
> We see that our planetary system is not a mere accidental aggregation of bodies. Masses of matter coming haphazard towards the sun would move as comets do, in orbits, always conic sections to be sure, but of every degree of eccentricity and inclination. There are a multitude of relations actually observed in the planetary system which are WHOLLY INDEPENDENT OF GRAVITATION AND DEMAND AN EXPLANATION.
>
> 1. The orbits are all *nearly circular.*
>
> 2. They are all nearly *in one plane* (excepting the cases of some of the little asteroids).
>
> 3. The revolution of all is *in the same direction.*
>
> 4. There is a curiously *regular progression of distance* (expressed by Bode's law, which, however, breaks down at Neptune).
>
> 5. There is a roughly regular *progression of density,* increasing both ways from Saturn, the least dense of all the planets in the system.
>
> As regards the planets themselves, we have:
>
> 6. The *plane* of the planet's rotation, *nearly coinciding with that of the orbit* (probably excepting Uranus).
>
> 7. The direction of the rotation *the same as that of the orbital revolution* (excepting probably Uranus and Neptune).
>
> 8. The *plane* of *orbital revolution of the satellites* coinciding nearly with that of the planet's rotation.

9. The *direction* of the satellite's revolution also coinciding *with that of the planet's rotation.*

10. The largest planets rotate most swiftly.

(The italics are all his, but the small caps are mine.)

## THE LAW OF GRAVITATION

It is a notorious fact that the computations for the Nautical Almanac are based, not on Newton's law of gravitation at all, but on a purely empirical corruption of it. The late Dr. Simon Newcomb, who for many years was at the head of that office in Washington, made no secret of the fact that all computations based upon the rigid law of the inverse square invariably disagree with Nature's own results, and that, in order to cure the discrepancies, he systematically tacked a minute decimal (.0000001574) onto the exponent *two.* Why the addition of this decimal was necessary, Newcomb confessed himself unable to explain; his only excuse being the familiar one of the schoolboy, namely, that it was the only way he could "get the answer in the book"! Indeed, Newcomb's method is now common among mathematical astronomers all the world over; although not all use his decimal, which is being "doctored" continually by many hands in futile efforts to get it "just right". Desirable though this object may be from a practical point of view, the really important thing, philosophically considered, is to explain the *origin* of the discrepancy. So long as this part continues unexplained, the very principle of universal gravitation remains on trial. Empiricism is not science. Indeed, is it not a historical fact that Newton at first stoically rejected his own theory of gravitation for precisely such a discrepancy? Here let me quote a few words from Professor Ernest W. Brown, the recognized chief authority to-day on the lunar theory (A. J. S., Dec., 1914):

> It appears now that [some of] the deviations of the moon from its calculated path cannot be accounted for by any gravitational cause. * * * From the agreement of the theoretical and ob-

> served motion of the moon's perigee I find that the index which the inverse square law contains does not differ from 2 by a fraction so great as 1/400,000,000.

And this, also, from the pen of Charles Lane Poor, Professor of Astronomy in Columbia University (*The Solar System*, p. 169):

> Le Verrier discovered a slight irregularity in the motion of Mercury, which for over a half a century has been a source of trouble to astronomers and *has led Newcomb to question the exactitude of the law of gravitation.* The perihelion of Mercury's orbit has a secular perturbation, or regular forward movement, amounting to 579."16 per century. Taking into account the disturbing action of all the known bodies in the solar system, Newcomb shows the law of gravitation will account for only 537."62; or the perihelion of Mercury moves forward along the plane of the orbit by some 41."54 per Century in a manner that cannot be accounted for. In his Astronomical Constants Newcomb dismisses many possible explanations of this anomalous motion, and after careful treatment discards them all as untenable. He shows that this motion cannot be due to erroneous determination of the masses of the various planets, nor to hitherto undiscovered planets. For a readjustment of the masses,or the introduction into the system of new bodies sufficiently large to explain the discrepancy, will introduce serious discordances into the motions of the other planets. He seems *to accept* as the most probable hypothesis, first propounded by Hall, *that the gravitation of the sun is not exactly as the inverse square* but that the exponent of the distance is 2.0000001574, instead of 2. He provisionally accepts this as a working theory and introduces it into the computation of his tables of planetary motion.

## THE SOURCE OF THE SUN'S HEAT

Newton sought to explain the light and heat of the sun by supposing the original chaos to have been composed of two main kinds of matter, luminous and non-luminous, and then picturing the Creator as segregating the first kind into the central body that we call the sun, and molding the rest into the earth, moon and planets. A century later Laplace postulated incandescence for his nebula and thence derived, not only our glowing luminary but the planets, also, in an original state of fusion. Shortly before the middle of the past century the theory of the mechanical equivalent of heat had its birth, and it was then immediately contended that the Nebula must have been cold to start with, but that the kinetic energy developed by the falling together of its component matter into the large bodies of the sun and planets initially heated them in a degree proportional to their respective masses. Mathematicians, however, soon showed that, so far, at least, as the sun was concerned, the new hypothesis was absurdly below requirements; and this finding it was that evoked the suggestion from Helmholtz that the sun is still a contracting body, that is to say, one in which the energy due to ''position'' is still in process of conversion into kinetic energy. Although this theory was tenaciously adhered to for decades, in spite of its geological contradictions, it finally succumbed to the joint attack of the mathematician's pencil and the new champion, Radium. But alas, and alas!, according to Doctor S. A. Mitchell (*Pop. Astr.*, June, 1913):

> From theoretical considerations we are positively convinced that there must be radium in the sun. But to prove this is another problem! With the spectra we already have, we can prove nothing but coincidences.

In a nutshell, then, the source of the sun's heat is still a wide-open question.

## THE GENESIS OF THE SOLAR SYSTEM

For nearly three quarters of a century, and until a decade or two ago, the Nebular Hypothesis of Laplace was generally esteemed as the true exposition of the *modus operandi* pursued by Nature in the evolution of the solar system. *Now* it is no longer so regarded by the great majority of astronomers, and, more particularly, by those who have made this subject a special study. Although it is quite true that numerous other hypotheses have arisen to compete for its vacated place, the fall of *the* Hypothesis has not been owing so much to their successful rivalry as to the belated recognition of its own glaring defects. As a matter of fact, never since Newton has the scientific problem of the genesis of the solar system been in a more chaotic and discouraging state than at this very time, in spite of, or perhaps because of, the distracting multiplicity of rival cosmogonies.

## THE COMETS

These objects remain as great a mystery to men of science of the twentieth century as to Newton and his generation. It is true that some new information has been gleaned from the spectra of comets, and also from a critical study of their orbital vagaries; but as to their origin and nature, and the causes of the peculiarities exhibited by their tails, practically nothing has yet been satisfactorily determined. Young sums it up by saying (Art. 737): "We have little certain knowledge on the subject."

## THE TIDES

There are two criteria, and two only, for testing the correctness of Newton's tidal theory. One of these was pointed out about a century and a half ago by the German philosopher, Immanuel Kant, who, relying upon the theory, demonstrated that the earth's rotation should be gradually slowing, and our day consequently lengthening. Since Kant's day, however, mathematicians have convinced themselves that the day has *not* lengthened, even infinitesimally; hence the tidal theory cannot on this count be sustained. The second, and doubtless more satisfactory, test is that of comparing the computations made on the basis of theory with the observations. This test has been repeatedly applied in anxious efforts to corroborate Newton, but invariably with results precisely the reverse. Sir George H. Darwin (son of the great naturalist), recently deceased, and the late Lord Kelvin, who to-day are everywhere esteemed as among the highest, if not the very highest, authorities on the tides, for a score of years collaborated together on this subject. It goes without saying that if these gentlemen, imbued as they were to the very last with unquestioning faith in Newton's tidal theories, could have found anything in the observed facts to warrant and support that belief, they would assuredly have jubilantly proclaimed it to the world. But what does Darwin really testify? He says (*The Tides,* p. 161):

> The equilibrium theory *is nearly as much wrong as possible* in respect to the time of high water. In fact in many places it is nearly low water at the time the equilibrium theory predicts high water. It would seem then as if the tidal action of the moon was actually to *repel* the water instead of attracting it, and *we are driven to ask whether this result can possibly be consistent with the theory of universal gravitation.*

Note this, also, from Doctor Young (*Gen'l Astr.,* p. 307):

> In fact *the statical theory* [of tides] *becomes utterly unsatisfactory* in regard to what actually takes place, and it is necessary to *depend almost entirely on the results of observation,* using the theory merely as a guide in the discussion of the observations.

## INDIVIDUAL CHARACTERISTICS OF THE PLANETS

Given a sound system of cosmology, scientists ought to be able to read the characters of the various planets from theoretical considerations, without depending supinely, as they do, on the evidence of the telescope. The fact of the matter, however, is that they know not how to establish by deduction a single planetary peculiarity that the telescope has revealed. They lack completely a sound method of interpretation. To them the question of Venus' axial rotation, for example, is a problem for the telescope or spectroscope, not for the mind to reason out. Surely, the province of science is to *interpret* Nature, not just to stare her out of countenance by main force!

## STELLAR PROBLEMS

Very much the same sort of criticism may be made respecting the present scientific methods of dealing with the problems presented by the stars. Nothing could excel the care, skill and industry with which astronomers have performed the drudgeries of observational investigation and mathematical computation, bringing virtually to a state of repletion the stock of ascertainable data wherewith to erect a sound and comprehensive uranography. Just here, however, is where their progress halts. The workmen have indeed provided and delivered to hand the building materials, but the architect has been wanting. What we want to know, and what astronomers cannot tell us, is, how this plethora of material is to be fitted together? We want to know, specifically, such things as these:

Is there a universe beyond our own? What is the meaning of the great aggregation of stars in the Milky Way? Why are so many millions of the stars *contemporaneously* brilliant? Is there any rule by which we can determine the intrinsic sizes of stars? What is the origin of the nebulæ? Why do they rotate? What is the explanation of their diversity of form? Why do the velocities of stars vary according to their spectral class? Are the stars all alike in chemical composition? How do they, in spite of gravity, preserve themselves aloof from one another? Why do "maturer" systems revolve more rapidly than those more youthful? Is there a central sun? Is there a maximum size to which stars can attain? What is the explanation of star streams? Why is the radius of the celestial circle of precession the same as the inclination of the earth's axis? What produces the sun's flight in space? What are the elements of its orbit?

To all such questions, elementary though they are, contemporary science returns no answers save of admitted speculation.

## THE DESTINY OF THE UNIVERSE

From the standpoint of general philosophy probably the chief cosmological query is as to the permanency or impermanency of the Present Order. According to the hierarchy of modern science, this order is not permanent, the great cosmic machine is "running down", and it is only a question of time till it shall destroy itself. College professors who have grown gray in the teaching of this vicious and altogether erroneous doctrine have doubtless become hardened to its monstrosity, for they seem to proclaim it in and out of season with every mark of proud paternity! For my part, I regard such a conclusion as, on the face of it, so gross a *reductio ad absurdum* as by itself to refute the entire process of ratiocination by which it has been reached, even if in its wake lay, one after another, complete solutions of all the paramount problems above considered, instead of the lengthening trail of incompetence and failure that really does mark it.

Recapitulating, then, we find our modern Argonauts of science starting out to explore and interpret the universe by, first of all, methodically casting overboard that heretofore faithful compass of mankind, the natural law of cause and effect; stigmatizing, as behind the times, those of us who continue to cling to the belief that mechanical effects, whether in the skies or in the laboratory, can derive existence only from preëxisting causes; decrying the notion that gravitation is an objective reality, and in its stead substituting the metaphysical abstraction of "position"; proclaiming by precept the law of the inverse square, and inconsistently employing an admittedly empirical formula in practice; setting up, one after another, and again and again, spurious hypotheses as to the origin of cosmic heat, seemingly for the mere sport of knocking them down; tendering us a job lot of cosmogonies from which to make choice, not one of which but flouts Nature and her laws; promulgating a theory of tides, then conclusively disproving it, and afterward, knowing its falsity, continuing nevertheless to teach it as true and as a "guide" to the observations; depending helplessly upon mechanical implements rather than upon the intelligence to interpret the planets; asseverating the random, haphazard and spontaneous nature of stellar motions, and in the same breath professing to be searching out the laws governing this randomness; and, finally, impugning the integrity of Nature and recklessly condemning her to ignominious death!

Here, then, is the net result of two centuries of Newtonian philosophy—of the labor of hundreds of thousands of individuals who, in one capacity or another, have bent themselves heart and soul to the task of solving these great problems, and of untold millions of treasure unstintingly poured out by philanthropists and governments to the same end! Who is there so blind as not to see that Newtonian science has reached the limit of its development? Like the Ptolemaic system, it is only an approximation to the ultimate truth, though, to be sure, a very much closer approximation. The epicycle system broke down of its own weight because there always remained, after each cycle superadded, a diminishing, yet still appreciable, discrepancy to be accounted for. Slight as this excess must have seemed at the last, its correction was destined never to be achieved by the then time-honored method, but only by a complete overturning of the system by Copernicus and Kepler. The full development of Newtonian theory has conducted us of this day to a strangely similar *impasse.* There is now that apparently trifling, but *really crucial* decimal of Newcomb's to be accounted for! Every effort of mathematics has been exerted to iron it out, but in vain; and it is only fair to conclude that *it is permanently beyond the power of prevailing theory to cope with.* I expect to prove to the satisfaction of the reader that the only way possible to overcome this obstacle is, by a revolution of the present-day science of astronomy no less drastic than that from the Ptolemaic to the Copernican, a revolution, too, which will abundantly justify itself by automatically solving all the paramount problems above enumerated.

## The Elusiveness of the Obvious

To my mind, the most striking mental peculiarity of mankind in the past has been its proneness, in all ages, to focus attention on the things at a distance rather than on those close at hand, to prefer the abstruse to the simple, the miraculous to the natural, the obscure to the obvious. In fact, the epochal events in the life of Astronomy have all been spectacular revelations of truths that ought to have been almost intuitively perceived. The conspicuous discs of the sun and moon, for instance, and the rounded outline of the earth's shadow thrown upon the latter in eclipses, are phenomena too plain, one would suppose, for even a thoughtful boy to misinterpret. How, again, men in their sanity could for fourteen centuries on end—as did the Ptolemaists—prefer to believe and to teach that the vast heavens rotate daily around our little grain of dust, instead of the latter turning upon its own axis, surpasses our modern understanding. It took fifteen centuries, from Ptolemy to Kepler, to evolve a mind capable of conceiving the simple notion that circulating bodies—the moon and planets—might turn around their primaries in another kind of curve than a circle, and it took even the great mind of Kepler a score of years of toilsome effort to gestate the thought. And yet, again, not until a paltry two centuries ago did a Newton arise to suggest and prove that gravitation extends beyond our atmosphere. It has been said of Bismarck that his success as a statesman largely lay in frankly avowing his true motives, because he had observed that openness in a diplomat was the last thing generally looked for, and hence was a better cloak than any form of deceit could be. The reason the obvious in Nature goes unrecognized so long is because artful man misdoubts her plain message and in a spirit of subtlety reads in a farrago of irrelevancies between the lines. Lovers of Dickens will recall Mr. Pickwick's momentous antiquarian discovery, on the premises of one Bill Stumps, of a stone bearing a curious legend out of which Mr. Pickwick drew some twenty-seven recondite meanings, when, as a matter of fact, according to the veracious graver himself, the inscription read, simply, "Bill Stumps, his mark". If Mr. Pickwick could come to "life" again, I fancy that he would find himself very much at home in the society of present-day astronomers.

A great orator has said that most men find it easy enough to believe in miracles having occurred two thousand or more years ago, or that they will again occur two thousand years hence, but that it is next to impossible to find any one credulous enough to believe in their happening to-day. Paraphrasing this epigram, I would say of astronomers that they do not hesitate to postulate miracles as taking place far up in the heavens, or deep in past time, while they indignantly scout the possibility of such things taking place right here and now. Thus, they impudently assume that stars and planets move spontaneously, but they are sane enough to know that bullets remain useless without powder; they nonchalantly assume that nebulæ revolve of their own accord, but would classify as defective a child that would expect as much of a mere squirrel-wheel.

## UNUM *versus* OMNES

On the theory of probabilities, the odds in every generation are a billion to one against the originator of an idea being right and the world wrong. This formidable preponderance of numbers against him has doubtless awed many a timid, but correct, thinker into silence, and cast many a stone in the path of human progress. Few of us, I dare say, ever stop to reflect that *every* valuable idea and item of information has incipently been handicapped by identically these odds, and that all that mankind has garnered, or can ever acquire, in the way of useful knowledge is merely the sum of these minority-of-one discoveries that have won their way through gauntlets of criticism to general acceptance. In every ship's company, at the close of every voyage, there is invariably *one* who must be the first to sight port. Natural truth exists independently of both human wishes and opinions, and cannot be settled one way or the other by a plebiscite, or even by a council of the wisest of one's own generation. It is related of Newton, for instance, that, although he survived for forty years the publication of his great work, *The Principia,* he did not have upwards of twenty followers in all England at the time of his death, and that it was not until ten years later that his doctrines were allowed to be taught at Cambridge and Oxford in competition with those of Descartes! Truly, a prophet is often without honor in his own generation as well as in his own country. O tempora! O mores! To-day Newton's fame fills the world, and a new generation has arisen that honors his opinions above Nature's truths, and even counts it a virtue to shield his errors against exposure and correction!

The generality of men labor under the delusion that in the serene domain of pure science the day is past when selfish considerations and bigotry cut a figure in its development. This is a pathetic mistake. Like any prosaic, commercial business, the established system of astronomy has been virtually capitalized in many ways, and this capital calls for protection from those holding its shares, and in proportion to the size of such holdings. Thousands of copyrighted books and pamphlets, the reputations of famous scholars, their salaried positions, and even their characters as sincere and truthful men, are, in a way, wagered upon the vindication of the traditional dogmas of the science. They vouch, in effect: that the universe is fleeting; that the law of gravitation is at once theoretically exact, but objectively inexact; that the law of equilibrium does not hold good of cosmic bodies; that their theory of tides is *per se* true, though false to nature; that gravitation is a mere abstraction and not a conservable force; that mechanical motions exist without antecedent causes—but the list is endless.

The question as to whether these doctrines are true or not, is no longer one for the profession of astronomers to decide, but *for the educated world at large.* To this latter court I now appeal. The highest astronomical court has time and again affirmed and reaffirmed these monstrous propositions, has repeatedly refused rearguments, and, in any event, is the real defendant in the matters at issue and cannot be prudently trusted to render a just and impartial decision in a suit involving the retention of all that it has so long stood for. Astronomers have long recognized that their real refuge is in sphinx-like silence, not in debate; in supercilious aloofness, and not in democratic fellowship; in the assumption of a pontifical authority that spurns alike question and questioner, and leaves the matter where it started. This is scarcely the place for private confidences, and so I forbear to cite specific instances in support of the testimony of hundreds more of the subtle influences at work to stifle candid criticism and muzzle the scientific skeptic. Of course, it is not to be expected that avowals of this policy of suppression, or by what underhand means it is designed to be made effective, should be published broadcast; yet that it is not a mere creation of a heated imagination but a substantial fact to be reckoned with, sufficiently appears between the lines of the following passage from the pen of Doctor Charles G. Abbot, the eminent Director of the Smithsonian Astrophysical Observatory at Washington. In his *magnum opus* (*The Sun,* p. 8) he says:

> Every large scientific institution or observatory has almost daily communications from persons of very moderate attainments who presume to question, nay rather to spurn, the most well-attested facts of human knowledge. Such persons seem to prefer especially to direct their attacks on the following facts: the Copernican system; the law of universal gravitation; the first and second laws of energy; and, finally, the high temperature of the sun. No argument can refute them, because they have not the requisite learning to comprehend it, which is no disgrace, but which should make men *modest* enough to have faith in *those who excel them immeasurably. Hence it is the policy of most scientific institutions to avoid entirely discussions of these subjects with such correspondents.*
>
> Professor Newcomb tells, in his *Reminiscences of an Astronomer,* of such a critic who called upon him and announced his disbelief in Sir Isaac Newton's theory of gravitation. Professor Newcomb proposed to the skeptic that he jump out of the window and convince himself of the existence of gravitation. Being thus pressed, the visitor stated that he believed that gravitation extended no further than the air, and did not go up to the moon. Professor Newcomb asked him if he had ever been there to see, and when his caller answered 'No', replied that, until one of them could go to the moon and try the experiment, he doubted if they could ever agree!

Since the initial publication of this work, in March, 1912, many of the ideas therein for the first time presented to the world have reappeared in the public prints, but always fugitively, in strange uniforms, and impressed into the service of alien doctrines that I have taken up arms against. This state of affairs leads me to emphasize the truism that a system of philosophy or science, such even as my own, like an automobile or any other complicated mechanical machine, is useful and valuable only *as an assembled whole.* What I have aimed to do, and what I venture to believe I have succeeded in accomplishing is, in Emerson's pregnant phrase, to reveal the universe "as a transparent law, not a mass of facts"; or, in concreter terms, as an eternal, self-energizing, self-regulating entity, coördinated throughout by a single (*necessarily* single) underlying dynamical principle—GRAVITATION. Some, indeed, may say that I have cast my net too wide; that I have presumptuously attempted to solve too many problems at one stroke. I do not myself think so; not, indeed, because I venture to assert that my offered solutions are conclusive and final, but because the very nature of my undertaking *involves* comprehensive treatment. A globe-map of the earth, however slightly filled in, is quite as essential to a correct knowledge of geography as a full complement of scattered maps of detail. In this book I seek to compress the universe about us into a single concept, a sort of mental universe-map, as it were, in which the sum of creation may be apprehended as the automatic unit that our intelligence tells us it *must* be in order to exhibit the infinite harmonies it does.

The process of building up a science such as astronomy has often been likened to that of erecting a great cathedral. The resemblance is palpable enough, but there is a contrast which here more deserves our notice. In the case of the cathedral, the design in the mind of the architect comes first in order of time, following which, bricks, stones and timber are all manufactured, cut and fashioned to fit their predestined places, and then respectively delivered upon the premises systematically so as to forestall possible mistakes and confusion. Morever, the architect takes the builder into his counsels, supplies him with duplicate plans and specifications, and in every other way coöperates with him throughout. In the case of constructing a science, all this is reversed. The designer never appears; there are no plans or specifications; facts —the building materials—are acquired haphazard and at awkward intervals; the very size of the foundation is unknown, as are likewise the height, the breadth and the general arrangement of the superstructure. Taking facts as they arrived, astronomers have tried to make progress as they went along, often mistaking capstone for cornerstone, cornice for girder, lintel for sill—in short, creating a structure, it is true, but one weirdly different from what it would have been had all the materials been available from the very outset. Now, thanks to time and human industry, all the facts are simultaneously before our eyes inviting and challenging us to test our architectual powers afresh. Shall we decline the challenge?

While it is true that my system is still so novel as not yet to have become authoritatively recognized and might, therefore, not unreasonably be supposed too untried for laymen to trust their unaided judgment upon, yet such seems to me its simplicity that I believe every studiously inclined reader who possesses even a sophomoric knowledge of descriptive astronomy will be able to follow my thesis step by step to its conclusion and form an intelligent opinion as to its merits. My special appeal is directed to that large body of professional men of scientific leanings who aim at broad generalizations as a means of classifying and memorizing the essentials of the sciences, believing, as I do, that among this class are to be found, in happiest combination, those primary judicial qualifications of impartiality, learning and discretion, of which the greatest and rarest is assuredly impartiality.

I regret exceedingly being unable, through force of circumstances that may be safely left to the reader's imagination, to embellish the work with helpful illustrations, and, for the same reason, being obliged to compress my material into the least possible compass. However, I comfort myself with the reflection that the handful of persons who may be drawn to read a work of this character will doubtless already be sufficiently familiar with the general facts of astronomy as to be able to supply from their own store of knowledge whatever may inadvertently be missing. To the scattered few who do not belong to this class, but who desire to improve their knowledge in this field, I respectfully recommend Flammarion and Gore's *Popular Astronomy* as incomparably the best general work, both for text and illustration, that has come under my notice. As a periodical stimulus to keep one's interest constantly aflame in this, the noblest and most enthralling of secular subjects, I would mention, with earnest commendation, the magazine of the same name, *Popular Astronomy,* published at Northfield, Minn.

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In order to give the reader a general idea of my system, before plunging into its detailed discussion and proofs, I respectfully invite his attention to the following list of a few of the

## *NOVEL FEATURES OF THE PROPOSED SYSTEM*

1. The present order of the universe is potentially eternal.

2. Newton's law of gravitation is literally exact in nature.

3. Hotness is the normal and persisting state of matter while under pressure. The sun is therefore perennially self-heating, and the temperature of stars is a function of their mass.

4. The fundamental law of equilibrium, namely, that freely falling bodies seek their lowest center of gravity, is of the prime essence of gravitation, and science

has committed a grave blunder in concluding too carelessly that by falling in vacuo bodies circumvent the law.

5. By basing my theory of tides on the strict law of equilibrium instead of on the spurious exception, I have succeeded in demonstrating; (1) that the heights of the tides are commensurate with the dynamical causes I assign to them, (2) that the times of high and low tides are *synchronous* with those causes, and not eight hours or more apart, (3) that the sun, and not the moon, is the chief cause of the tides, notwithstanding the seeming paradox, and (4) that, far from retarding the earth's axial rotation, the tides actually cause it!

6. The principle of gravitation is not restricted to the limits of our system, as Newton construed it, but extends throughout and across the whole length and breadth of the universe, organizing the latter into a single coördinate unit.

7. The true pole of the ecliptic is a mathematical point situated about a half light year from us, in the line of the earth's axis extended, and marks the direction in which our solar system is falling in response to the joint, or resultant, attraction of the stars.

8. However, we are not falling in a direct line, but in a huge conical spiral path, like that of a circling falcon approaching the earth. The length of a single coil of this spiral is approximately five million, million miles, its describing period about 26,000 years, and its mean plane very nearly that of the ecliptic. The apex and antapex of the sun's way are respectively the fore and aft celestial ends of the double tangent to this curve passing through the sun's center.

9. This movement of the solar system is due to the gyroscopic reaction resulting from the whirling of the system in the opposite direction about its own axis.

10. The revolution of the planets around the sun is a vortical, or whirlpool, effect produced and maintained

by the gravitational suction emanating from the stars and drawing us toward the true pole of the ecliptic; and the same explanation applies equally to the rotations of the subordinate systems around their respective primaries.

11. The earth is a simple object in the act of falling, forever poised on its lowest center of gravity. Its heavier, or lower, hemisphere is, of course, the northern, as the position of the continents sufficiently testifies.

12. The sun (a typical star) is essentially a hollow sphere normally undergoing every instant multitudinous minor explosions all over his vast surface. His periodical "spots" are due to this cause, only on a larger scale, and their periodicity, it will be found, is susceptible of ready explanation. Morever, every 100,000 years or so the sun explodes centrally, with such extreme violence as to become what is technically known as a "temporary" or "new" star, giving rise, by the same token, to a "nebula", or cloud of molten *débris,* which the circulating planets, ever spinning in their orbits, gradually sweep up, and eventually clear away, save for some lingering vestiges of impalpable dust that we perceive on dark nights as the "zodiacal light" and "gegenschein."

13. Comets are fragments injected into our system by neighboring stars, and their peculiarities are all traceable to the circumstance of their advent having been too recent to allow time for their complete assimilation. Asteroids, or at least some of them, are what may be termed *domesticated comets.*

14. The Milky Way is a vortical ring of stars revolving under the influence of the resultant of the attractions of an immeasurably greater "universe" than itself. However, be the material universe finite or infinite in fact, there is nothing in my theory inconsistent with either hypothesis.

15. Viewing the physical universe in its broad philosophical aspect as the creation of a Designer, I incline toward the conclusion that the organization of the

sum of the universe into a coördinated whole is not the ulterior purpose, but rather a necessary first condition to the production, operation and development of its component individual planetary systems. For, only in these relatively minute units alone do the conditions exist for the generation, propagation, and evolution of living organisms, which *is* the Ulterior Purpose. The Cycle of this Evolution is not, as heretofore supposed, from the first forming of a star out of cosmic dust to the final condition of a dark, cold, inert clinker, but from one solar paroxysmal explosion to the next—From Nebula to Nebula,—a cycle endlessly repeated, with infinite permutations and combinations.

## II

# NEWTON'S THEORY OF PLANETARY MOTIONS

PERHAPS the first system of celestial motions meriting the name scientific was that devised by Claudius Ptolemy, who lived about the middle of the second century of our era. According to him, the earth was the center of the universe around which revolved daily, in the order of their supposed distances from it, the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn, and the stars. Beyond the stars, again, was the *Primum Mobile,* or Prime Mover. To prevent the planets and stars from falling down upon the earth, Ptolemy conceived of them as set in separate crystalline spheres; and these latter, he supposed, by the noises of their rotation, produced the ''music of the spheres''. Strange to say, this notion of celestial harmonies survived the discovery of Copernicus, for Kepler speaks of it, and assigns to Jupiter and Saturn the bass, to Mars the tenor, to Venus the Contralto, and to Mercury the soprano parts in this heavenly chorus.

Having assumed that all the celestial bodies rotated around our earth, it was quite natural to surmise, in the first instance, that they did so in exact circles. In our practical age we should be apt to do the same, were we approaching the problem for the first time; but if we should then speedily find that observation materially contradicted theory, we would doubtless promptly try out some other sort of curve in the effort to find a short cut. This simple expedient the ancients seem never to have thought of, for those were the halcyon days of deductive philosophy, when man sought to solve nature by presumptuously trying to read the mind of the Infinite by divination, instead of indirectly, through His works. They reasoned, metaphysically, that the Creator would not choose any but the "perfect curve" for the paths of the celestial bodies; and they would have accounted it blasphemy in anyone who might have suggested an alternative idea. Accordingly, when systematic observation showed certain vagaries of movement on the part of the planets, instead of adopting the obvious course and experimenting with other possible curves, they invented the device known as epicycles;—that is to say, they imagined the planet, in addition to revolving in one great circle, to revolve also in a second, smaller circle, whose center, rather than the planet's center, progressed along the circumference of the main curve. One such epicycle proving insufficient, nowise daunted, they postulated a second epicycle grafted upon the first, and so on indefinitely, until, by the time of Copernicus, they had as many as seventy such arrangements piled one upon the other!

Such, then, was the state of theoretical astronomy at the close of the regime of the Ptolemaic system, whose rule, though not actually ended, was at least foredoomed by the publication of Nicholas Copernicus' (1473-1543) great work, *De Orbium Coelestium Revolutionibus,* in the very year of the author's death. In this treatise Copernicus taught that the sun, and not the earth, is the center of our system, that the moon revolves around the earth, and that the earth and all the rest of the then known planets revolve around the sun in *circular* orbits. The only material mistake he made lay in perpetuating this last doctrine, inherited, as it was, from the older system; but in extenuation it should be mentioned that the general reform brought about by him was so basic as to render for a time unavailable the tangled skein of mathematical material accumulated by his predecessors.

As things turned out, it would have been a lasting reflection on the perspicacity of philosophers had the discoveries of Copernicus been delayed a half century or so longer; for by that time Galileo (1564-1642) had improved the telescope, and with its help had observed the phases of Venus and followed the satellite system of Jupiter through several cycles of rotation. Had Copernicus been in possession of these significant facts, much of the glory of his achievement would have been lost.

Fortunately, the cycle and epicycle fallacy, too, was destined not to survive long; for John Kepler (1571-1630), in the year 1627, gave it its quietus when he published his three laws of planetary motion, as follows:

1. *The planets revolve in ellipses.*

2. *The radius vector passes over equal areas in equal times.*

3. *The cubes of their mean distances are proportional to the squares of their periodic times.*

Although later researches have shown these laws not to be exactly true, they are so close an approximation to the truth that modern astronomers seem to have tacitly agreed among themselves to shut their eyes to the observed discrepancies as immaterial—alas, to the very great detriment of the science! In estimating the true value of Kepler's contribution to astronomy, it is important to remember that his discoveries were purely empirical, and that they were arrived at without reference either to the principle of gravitation or to the fact of the sun's flight. The story of Kepler's labors and privations in the pursuit of his quest is a tragic one, all the more so because of the perverse genius he displayed in so long eluding the obvious. If only he had had the sagacity when he began his labors to ask himself the seemingly self-propounding question,—May not the planets move in curves *other than circles?*—he would unquestionably have shortened to a period of weeks, or even days, the score of years that his task actually consumed. What a travesty on human intelligence! Fourteen centuries to evolve the simple idea that the earth, instead of the universe, rotates on its axis once in twenty-four hours! Fifteen centuries to prompt the query,—Why may not the planetary orbits be other than circular? These two ideas, epochal though they proved, were by no means strokes of genius, but only the prosaic promptings of common sense erupting through the smothering strata of superstition, tradition, and mathematical abstrusities that the wiseacres of earlier centuries had heaped up. So far as the mathematical proof was concerned, that was only a matter of rules and industry, once given the clue. Clearly, the two most important lessons of astronomical history are, (1) that vigilant skepticism is the price of progress, and (2) that investigation should begin with the near and obvious.

The next great name in the development of the science is that of René Descartes (1596-1650), although he is seldom thought of as an astronomer, but rather as a philosopher and mathematician. I mention him here, partly because it was his cult whose ascendancy over the world of thought for almost a century after his death was great enough to bar out of England's schools the teachings of her own son, Sir Isaac Newton (1642-1727), during the whole of that philosopher's long life, and partly because he, Descartes, was the originator of the *Vortical* theory of planetary motions; a theory which, though utterly impractical as he conceived it, we shall nevertheless find to be true in principle when combined with the workings of universal gravitation.

It is with sincere regret that I must confess my inability to share the world's extravagant estimate of Newton *as a philosophical astronomer.* As a mathematician he may possibly have been supreme; but of this I am not competent to judge. Was it not Huxley who first said that you cannot take out of mathematics more than you put in it—meaning, that if you start figuring upon false premises you cannot arrive at useful results? Because a man is a mathematical genius, does not signify that he is equally great, or even great at all, as a theorist or constructor. Ptolemy was a mathematician of the first order, but his crystalline spheres and epicycles were, for all that, fantastic unrealities. In our day the Nebular Hypothesis of Laplace (perhaps a greater natural mathematician than Newton) was universally hailed as the supremest conception of man, but we have lived to see it laid aside. Newton, too, O hero-worshiping reader, was ordinary flesh and blood like ourselves, and fallible even as Ptolemy or Laplace. Not only that, but he lived in an age when the bible was still regarded as a scientific authority; when the Inquisition was not yet dead; when witch-burning was a religious rite; when the earth and the entire solar system were generally believed to be only a few thousand years old; when Uranus, Neptune and the asteroids had not yet been discovered; when the sun's motion was not even guessed; when the spectroscope was undreamed of; before the mechanical theory of heat was discovered; before the accuracy of his law of the inverse square had been impugned; and before his theory of tides had been weighed in the balance and found wanting. Shall we now wave aside these important considerations, and, with the bigot's finality, proclaim that "Newton's science is good enough for us", and that, hedged about though he was with the narrow limitations of his age, he could commit no error? Now that we know so many more basic astronomical facts than Newton did, why should we seek to crowd them all into the superstructure of theory only, rather than to employ them in broadening, strengthening, repairing, and remodeling *the foundations* that stand in such sore need of attention?

For a reason easy enough to understand, the field of astronomy since Newton's death particularly, has become monopolized by mathematicians to the exclusion of everyone else. Far be it from me to decry mathematics as such, since it is verily the only exact science we have, or to charge mathematicians, as a class, with being worse versed in their subject than other professional men in theirs. On the other hand, I can scarcely agree with Doctor Abbot that mathematicians so "immeasurably excel" their fellowmen that they can afford to despise extraneous suggestions, nor with Doctor Thomas Jefferson Jackson See, the celebrated mathematician and astronomer, who says, "not only must the astronomer be the wisest and intellectually the most penetrating of men, but in order to be a discoverer of the first order he must be just in his habits of mind and wholly devoted to the truth." As long as mathematicians exclusively preëmpt the field of astronomy and at the same time continue to entertain such complacent sentiments regarding themselves, it will be vain to expect any radical reform within their ranks, however much it may be needed.

The expression, "figures don't lie", is the vulgar equivalent of, "mathematics is an exact science." But the figures we start with *must be accurate,* and no degree of mathematical skill can bring out a correct result unless they are. It is related of a certain noted bridge-architect, now deceased, that he bankrupted his concern by neglecting, in one of his otherwise accurate estimates, the little formality of multiplying his final result by two, overlooking for the moment that every bridge must have two sides.

Now, the simple moral of this digression is, that Newton, in his attempt to solve the dynamical problems of the universe, neglected to take into the reckoning several essential factors in his problem—(for the very good reason that he did not know of their existence)—hence his theories and conclusions, if not absolutely worthless, are at least *amendable.* He assumed that the solar system was a universe unto itself, completely independent of and dissociated from the stars in general. When, therefore, he spoke of gravitation as being "universal", he misused that adjective, inasmuch as he incongruously restricted its application to what we know now is little more than a molecule in the total universe of matter. In other words, he took into consideration only the mutual attractions within the system, but he did *not* take into account the stupendous reactions upon that system arising out of the attraction between it, on the one hand, and *the rest of the universe,* on the other. Like the bridge architect, he failed to multiply by two!

It seems wonderfully strange to me that, of all the brilliant minds that have heretofore applied themselves to the theory of astronomy since Newton, not one has so much as suggested *the utilization of the energy inherent in our cosmic fall* to account for the gyrations of the planets and satellites, and especially for their multitudinous *concordances.* Following the lead of Newton, one after another of them has fallen blindly into line and kept in the same old rut. Newton, of course, is more to be excused than the rest; for he was not in possession of certain essential factors, and, besides, he was so far ahead of his own generation that not even his modest postulate that gravitation extends as far as the moon was accepted by it during his lifetime, though he survived, as was stated before, the publication of his *Principia* for as much as four decades. The oversight, futhermore, appears all the greater when we remember with what assiduity mathematicians have devoted themselves to the investigation of the purely academical and altogether speculative "fourth dimension of space", the while remaining stone blind to this genuine *third dynamical dimension* of the real cosmos. To them, just as to Newton, the solar system is, to all intents and purposes, a world of two dimensions, in which the mutual attractions of the members take place *in a single plane,* the plane of the ecliptic; and they seem never to have taken thought to look up or down from that level in search of an extraneous motive power acting transversely. *The universe of Newton's conception lacked the dynamical dimension of* THICKNESS.

I trust that I have now said enough to convince the unprejudiced reader that there is plenty of room for improvement in the theory of astronomy as now taught in the schools, and to prepare his mind to receive new impressions and reconsider past judgments.

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When, at the age of twenty-three, as the story goes, Newton saw the apple fall, the thought that occurred to him was not single but duplex. One phase of it was, Does the force of gravitation extend as far as from the earth to the moon?, and the other, If it does so extend, then why does the moon not fall, but preserve its uniform distance from age to age? Doubtless thousands of men before him had asked themselves the same queries, but given them up as unanswerable conundrums. Newton, however, did not. It occurred to him that, supposing the moon at every mathematical point of her orbit to be directed, with undiminishing velocity, tangentially forward, she might still fall like the apple, but fall no farther than just from the line of the tangent to the rim of the orbit. The first time he made his calculation the result was so far out that he gave up his hypothesis as unsound, and charged his labors to profit and loss. Some years later, however, as luck would have it, one of the chief data of fact upon which he had relied, namely, the length of a terrestrial degree, was found to be erroneous, and when this corrected quantity was incorporated in his earlier calculation the result came out satisfactory. His chief doctrines are:

1. *Every body continues in its state of rest or of uniform motion in a straight line, unless it be compelled by impressed force to change that state.*

2. *Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which the force acts.*

3. *To every action there is always an equal and contrary reaction, or the mutual actions of any two bodies are always equal and oppositely directed.*

His law of gravitation is: *Particles of matter attract each other directly as the product of their masses and inversely as the square of the intervening distance.*

By way of a supplement to these laws, I quote a passage from Young's work (*Gen'l Astr.,* Art. 421):

> Newton was not satisfied with merely showing that the principal motions of the planets and the moon could be explained by the law of gravitation; but he went on to investigate the converse problem, and to determine what must be the motions necessary under that law. He found that the orbit of a body moving around a central mass is not of necessity a circle, or even a nearly circular ellipse like the planetary orbits, but that it may be a *conic section* of any eccentricity whatever—a circle, ellipse, parabola, or even an hyperbola, *but it must be a conic.*

Now, in order to set myself straight with the reader, I wish to assure him that I am entirely in accord with these principles, both in letter and spirit; but that I am not at all in accord with Newton or his followers; for the very good reason that *they do not practice their own precepts!*

In investigating the laws of circulating bodies, it has been customary from the time of Newton to take, as the typical case, that of the earth and the moon, and from that to generalize as to all. Let us follow their example; but first let me prepare the way, so that we may have a clearer conception of the magnitude and complexity of the problem before us than even the astronomers possess, or, rather, than they are willing to admit they possess.

Most people imagine that it is an easy matter to draw a perfectly straight line. Such a thing is not possible for any human being, and even if it were accidentally accomplished, there would be no available standard by which the fact could be attested. It is said that the flattest piece of metal in existence, though fashioned with great care, is not flatter than the rotundity of the moon. The curvature of the ocean, level as it may seem to us when looking directly down upon it, slopes away from its tangent about eight inches in the first mile. Compare this now with the curvature of the moon's orbit, which, according to mathematical calculation, swerves from its tangent only 1/10 of an inch in a mile, or .0535 inches in one second of time, during which it travels 3350 feet.

The mean distance of the moon from the earth is 238,840 miles, according to Young. Astronomers have attempted to explain how it got there, saying it was originally a part of the earth and by their mutual attraction has been gradually forced out to its present position; others, that it came from a distance, and when it approached near enough, was lassoed by the earth's attraction; and Newton himself, that the Creator placed it in position.

Now, considered merely as an isolated fact, it would make very little difference to us whether the moon were a few miles further in or further out; but it makes all the difference in the world when this *distance is taken in connection with the velocity of the moon in her orbit.* For the feasibility of the Newtonian hypothesis presupposes the *precisest, undeviating correspondence between the length of the space fallen through by the moon in one second of time and the rate of her tangential velocity per second,* else must she fall to, or escape from, the earth. This point may be made clearer by a reference to Figure 1, copied from Sir Oliver Lodge's book, *Pioneers of Science* (p. 171), with the text accompanying it:

> Now consider circular motion in the same way, say a ball whirled round by a string.
>
> Attending to the body at O, it is for an instant moving towards A, and if no force acted it would get to A in a time which, for brevity, we may call a second. But a force, the pull of the string, is continually drawing it towards S, and so it really finds itself at P, having described the circular arc OP, which may be considered to be compounded of, and analyzable into the rectilinear motion OA and the drop AP. At P it is for an instant moving towards B, and the same process therefore carries it to Q; in the third second it gets to R; and so on: always falling, so to speak, from its natural rectilinear path, towards the centre, but never getting any nearer to the centre.
>
> The force with which it has thus to be constantly pulled in towards the centre, or, which is the same thing, the force with which it is tugging at whatever constraint it is that holds it in, is $\frac{m\,v^2}{r}$; where $m$ is the mass of the particle, $v$ its velocity, and $r$ the radius of its circle of movement. This is the formula first given by Huyghens for centrifugal force.

But suppose that, for any reason whatsoever, as by etheric or meteoric resistance, the moon's momentum (which the reader should never forget is, according to Newtonian theory, altogether unexplained) should not avail to carry her clear to A, but only to some point by ever so little short of it, then the moon would inevitably sink at P within the line of her orbit, that is, nearer to the earth, where the latter's attraction would become even greater, absolutely and relatively, and consequently, during the succeeding second, overmatch the tangential velocity still more; a process which could not be stayed and

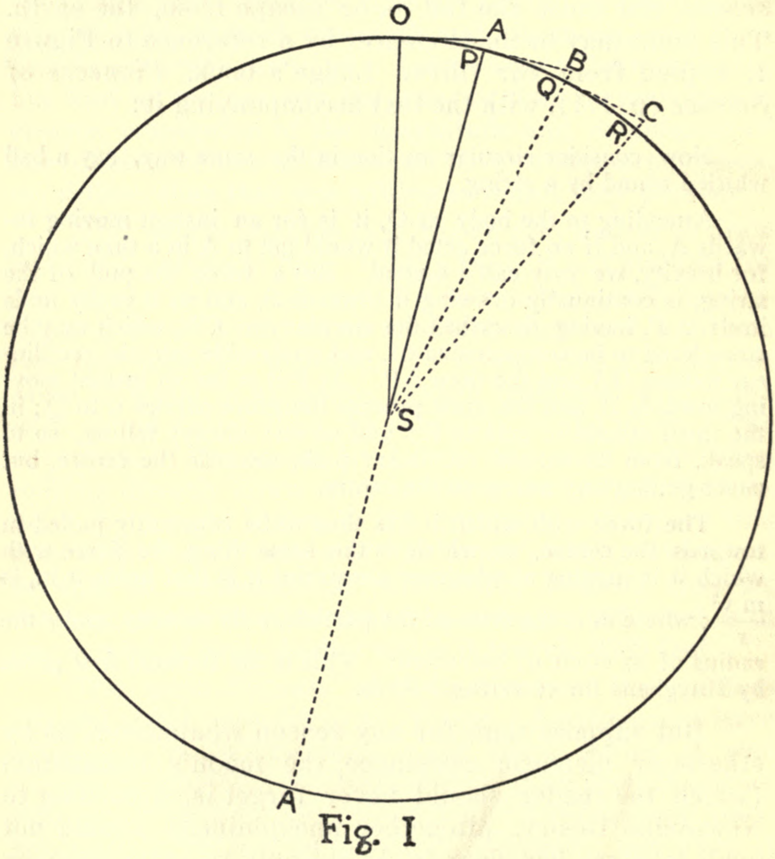

Fig. I

would inevitably rapidly precipitate the moon upon our heads. On the other hand, suppose the tangential velocity to be ever so slightly excessive, so that the moon in its initial second of time could not at P drop clear to the orbital line, then would the earth's attraction, relatively and absolutely, acceleratingly *decrease* more and more, and the moon would consequently escape irrecoverably into space.

So precarious an arrangement as this surely cannot be the cosmic fact! Newton, with his hypothesis of divine agency, had a great tactical advantage over the proponents of spontaneous motions, who, no doubt, imagine that their hypothesis covers the requirements as responsively as his. But they are vastly mistaken. Were Newton here to answer us, he could consistently retort that the Creator is omnipotent; that it was within His power to place the moon just where He pleased; that He could at will fling it even more accurately than any mathematician could compute its proper course, and that He could impress upon it such velocity as He listed. Moreover, Newton might add, the Divinity still watches over His universe and by His mere fiat can readjust it, when and where needed, just as effectually as when He created it. Do I hear any astronomer make like claims of conscious design on the part of inanimate nature?

Now, in the solar system there are eight major planets, some twenty-five satellites, and more than 700 asteroids, all of whose orbits are very much larger than that of the moon, and whose trajectories consequently are infinitely straighter. Are we to believe that these, too, have uncaused motions, that these motions are all miraculously tangential, and that their speeds are magically accommodated by mere accident to the strength of their several central forces?

The vicious habit of the Newtonians of covering up the flaws of their theories was broken in upon in one notable instance. This was when Laplace, deceived into thinking that he had in his Nebular Hypothesis the key to their answer, pointed out the amazing inadequacies of

Newton's theories as they stood then, and, for that matter, still stand. He called attention to the fact that all the planets revolve in nearly the same plane, that they revolve all in the same sense, that their orbits are almost circular, that the axial rotations of the planets show similar uniformities, that the revolutions of their satellites do so likewise, *and that Newton's theories throw no light whatsoever on these significant concordances.* Continuing, he demonstrated, on the theory of probabilities, that the chances of all these concordances happening together were as one against billions of billions. This, too, before the discovery of Neptune, of all save four asteroids, and of most of the satellites! To-day the Nebular Hypothesis is practically defunct, and nothing has arisen to fill its place—but the difficulties Laplace pointed out still are there, and are still clamoring for dynamical explanation. Shall we not judge Newton's system by its negative qualities, by its many sins of omission, as well as by its positive merits?

If you will tie one end of an elastic string to a small solid ball and, keeping the other end of the string in your hand, whirl the object round and round, you will find the tension on the string increase and the string itself lengthen the faster the whirling is done. Nor can you fail to note that, with each turn, you mechanically execute with your hand a FLINGING MOTION; stop *that* and the ball will instantly fly back at you with force. You might, perhaps, suppose that the energy you applied in this way all went toward overcoming the resistance of the atmosphere, but this is not so, as you may easily prove to yourself by trying the experiment over again with a large *hollow* ball of the same weight as the solid one. Let me ask you in all frankness, do you see any analogy between this experiment and the case of the earth and the moon? The "string" of gravitational attraction is indeed there, *but can you point out to me any equivalent action on the part of the earth, any whirling maneuver, that fills the place of the flinging motion of your hand?* I know you cannot, nor can the sophisticated astronomers, themselves, who nevertheless *imply* there is. Why, then, does the moon keep her distance, and why does she course round and round, instead of yielding to the tension of the connecting cord and flying back against us? It is a continual shock to me to find such men as Flammarion and our own Doctor W. W. Campbell, men of the first order of merit, not to mention an endless procession of lesser experts, talk with straight faces about "the sun whirling the earth around", and a "star whirling its companion around",—with never an attempt then, or at any other time, in the class-room, laboratory, or printed word, to justify the expression, or to apologize for the palpable misrepresentation!

Have you, my reader, any adequate idea of the elastic strength of the earth's attraction upon the moon? Do you realize that, unlike a rubber band, gravitational attraction never rots or wears out, never relaxes, and, moreover, even *increases* its tension the closer the bodies are brought together? It is not like a strand of twine, or a ship's cable, or a dog's tether, that remains in a state of laxity until called into play only when stretched to full length. No! it is *unrelentingly* pulling at the moon with all its might, striving to bring her down.

Now, it is not a difficult matter to determine by calculation the approximate strength of this attraction, once we know the respective masses of the two bodies and the intervening distance, all of which we do. Expressed one way, this attraction is equivalent to the full tensile strength of a solid steel cable 400 miles in diameter (say from Pittsburgh to New York) capable of sustaining a load of 40 tons to the square inch. Expressed in terms of power (supposing a horse able to sustain a ton against gravity), it is equal to that of 240 million, million horses. Allowing 100 square feet for each horse, it would require to stable them a four-story building covering the entire surface of the earth, not excepting the space taken up by the oceans! Visualize all this to your mind's eye, and imagine the horses, or a steam engine equal to them in power, located at the center of the earth and pulling upon such a cable, and ask yourself whether it seems to you reasonable that the unsupported moon, *without any influx of energy whatsoever from without,* can, unenfeebled, hold her own against it forever, as astronomers declare she can? To the casual observer, the moon looks like a silver wafer pasted upon the sky; in reality it is a globe of earthy matter 2160 miles in diameter (as far as from New York to Santa Fé) with a mass nearly one-eightieth that of the earth itself. So far as we know or have reason to believe, it has remained exactly at its present mean height for at least 3000 years, and possibly has been there for as many hundreds of millions—all the time pulling against a strain of 240 trillions of untiring horses! The moon has no pillar to support it, no pulley to suspend it, no atmosphere to buoy it, no breeze to waft it, no screw to propel it, no engine to haul it,—yet still it stays up. Why? Whence comes the centrifugal force to keep driving it away from the earth with identically the same energy that the latter perpetually prompts it to fall? Where is the equivalent of that flinging motion of your hand that supplied the centrifugal force to the little metal ball of our experiment? To this query astronomers with one accord reply: "The moon's innate momentum constitutes this sustaining power," and then they immediately fall mute. Let us see what merit lies in this answer:

To go back to our elastic string and metal ball; suppose you hold tight one end of the cord, while I pull the ball away from you until we both sense the tension on the string. Here your hand, say, represents the earth, the tensed string the gravitational attraction, and the ball the moon. Suppose, now, that I should let go the ball, what will become of it? Will it fly toward your hand, or will it, *of itself,* take on a tangential movement and revolve around you in a circle? Of course it will fly to your hand! To do otherwise, we all should agree, were *unnatural.* When astronomers, therefore, pretend that the moon has a *spontaneous* tangential motion, they know as well as we that such a motion is physically impossible under the present order of nature, and that they must presuppose a pre-existent order, or a realm of present nature far removed from us, whence to derive such a miracle. Admit, for the sake of further argument, that there once existed a time when miracles were the rule and natural order the exception, or that such a condition exists to-day in the sky above us; then what possible use is it for us to try to solve the dynamical problems of the celestial universe at all, since we cannot sanely hope to differentiate what is miracle from what is natural, or consistently fit one to the other? Once assert that mechanical effects, such as the rectilinear motions of stars and planets undoubtedly are, exist independently of physical causation, and you commit four grave follies; (1) You deprive physical science of the only ground she has to stand upon, namely, the law of physical cause and effect, the sole key to the interpretation of nature; (2) You throw wide the door to the perpetration of all sorts of other pious frauds; for if Nature departs from her laws in one case, why may she not do so in any other, according to the exigency of theory or the whim of any of her would-be interpreters? (3) You commit yourself irrevocably to the hopeless task of trying to correlate facts with miracles, instead of facts with cognate facts; and (4) You require of the present order of Nature not only to regulate itself, but likewise to overcome and discipline the erratic elements left over or inherited from a previous state of chaos.

Again, continuing our experiment; suppose that instead of letting the ball go, I should fire it from a gun; could I do so, practically or theoretically, with such velocity as would carry it around your hand, in a near circle, back to the identical starting point? Or, suppose that having started the ball whirling in the ordinary way until you had it going with a uniform motion; could you, by a sudden and doubly violent swing, cause the ball to make *two* uniform turns in succession instead of but the one? Astronomers virtually say both these things are possible in the case of the moon, because the ether of space is non-resisting, whereas the air offers considerable resistance. That they are wrong, the experimenter may see for himself. For one thing, he knows that only a minor part of the energy he puts into the flinging motion goes toward overcoming the air resistance; (2) that the momentum of the ball is only the energy he himself imparts, and that it dies out almost instantly the moment his flinging maneuver ceases; and (3) that the great bulk of the energy his hand supplies is absorbed in stretching the string, or keeping it taut; that is to say, his *muscle* is the centrifugal force. You cannot hitch in double harness a bullet fired with a charge of gunpowder equivalent to 10 horse-power hours of energy along with the horse itself, and expect them to team a load for ten hours. *No more can you match a projectile moon with the steady pull of gravity.*

Now, it is not at all difficult to determine the approximate horse-power hours of energy resident in the moon's "momentum". Assuming that the moon is moving at the exact velocity of 3350 feet a second and that it is falling at the behest of the earth's attraction at the precise rate of one-nineteenth of an inch in the same space of time, we need only divide the fraction into the larger number and multiply the quotient by 240 trillions to get the answer desired. Remember, however, and again I say remember, that, *according to Newton's theory,* the moon has no way to recuperate lost energy; hence, when the energy of her momentum is used up in wrestling against the earth's attraction, that momentum is done for, for good. Now, by the conditions of our problem, the moon's momental (inertial) energy is constantly pitted against the earth's attraction, which is always fresh, can never be used up, and is uniformly self-renewing. Dividing, therefore, as we did above, 3350 feet, or its equivalent in inches, 40200, by 1-19 we obtain the quantity 763,800, which is the number of seconds that it should take the centripetal attraction to wear out the moon's momental energy *completely.* Raised to higher terms, this period amounts to 8.8 days, which is reasonably close to the time generally estimated that it would take the moon to fall to the earth if dropped from a state of absolute rest. This result agrees well with the rule that "projectiles fired horizontally reach *the earth simultaneously with other objects like them dropped from the same height"*, a rule that only Newtonians disregard.

Let us reduce the argument to mathematical form: According both to theory and observation, the moon at perigee has always exactly the same momentum. Considering, then, two successive perigees, let $M$ represent the Moon's momentum at the time of the first perigee, and $M'$ that which she has at the time of the second, and we have,

$$M=M'$$

Again, by general consent the centripetal and centrifugal forces are equal, which fact we may express, for one lunation, thus:

$$C=C'$$

But astronomers inform us that the momentum, $M$, of the moon supplies the centrifugal force, consequently, on this theory, the momentum of the moon at the second perigee must be M-C′; substituting which in place of $M'$ in the first equation, we get,

$$M=M-C'$$

whence, $C'=0$

and, since $C=C'$ $C=0$

*Reductio ad absurdum*: There are no central forces: gravitation is a myth! (V. p. 4.)

You may be curious to learn how scientists try to overcome this seeming *impasse*. Very characteristically! Herbert Spencer, innocently aided by Huxley, about the year 1860, invented the euphonious phrase, "persistence of force." This expression, primarily intended for use in physics as an improvement on the phrase, "conservation of energy", quickly commended itself to the astronomical profession as an excellent substitute for Newton's word "inertia." This word inertia, in fact, has fallen of late so much into disfavor that seldom does the eye meet it in modern books on astronomy. *Persistence = inertia!* First, we are expected to concede the existence of *uncaused motions*, and now we are being unctuously cajoled into admitting that persistence and inertia are synonyms! Imagine the cultured Bostonian father predicting great things for the infantile Waldo because of his "superabundance of inertia!"

Again, does the moon really fall toward the earth as astronomers allege? It is admitted, on all hands, that its mean distance is quite, or at least very nearly, the same from month to month and from century to century. If it be correct to say that the moon is falling simply because it is continually diverging from the tangent of its orbit, it is no less correct to assert that the dome on the Capitol at Washington is falling, because it, too, is continually diverging from the tangent of the circle in which it revolves by reason of the earth's diurnal rotation; specifically, three inches per second. According to the doctrine of the conservation of energy, loss of "position" involves transformation of potential energy into kinetic, and for every unit of the former that disappears one of the latter must appear. If such be not the case in *every* instance, the law is no law at all, and must be relegated to the limbo of exploded errors. In one ordinary month there are about 2,551,400 seconds, or 708.7, hours, or 29.5306 days. If in one second of time, as alleged, the moon falls .0535 ins., it should develop kinetic energy equal to 240 million, million horse-power as long as the falling process continues, which, humanly speaking, means forever. What becomes of this energy, I ask? If nothing becomes of it and it passes out of existence in the moment of its creation, then must we not admit that there exists a creative energy in nature and also a way whereby energy can perish, neither of which propositions scientists now concede? If *no* potential energy, on the other hand, disappears and no kinetic energy appears, then there is no loss of "position" at all, the moon is *not* falling, and the whole Newtonian argument breaks down. Lastly, if the moon is *not* falling earthward, it is not construable as a body falling *in vacuo,* hence she must be obeying the law of lowest center of gravity with respect to the earth, and this should suffice as the reason for her "constantly turning the same face toward us". For the same reason, the earth should not be construed as a falling body with reference to the moon; hence the Newtonian tidal theory is erroneous!

The figure on page 34, to which attention has once before been directed, is that usually employed by writers and teachers to illustrate Newton's doctrine. The "explanation" runs thus:

Suppose that the moon originally started from the point O with a velocity capable of carrying her along the tangent to the point A. Instead of arriving at A, however, on account of the earth's attraction she arrives at P, having followed the arc in place of the tangent, and so on." That phrase, "and so on", is part of the explanation, and is as far as it ever goes, as far as the theorists *dare* go. They stop precisely at the point where the trouble begins! Every tyro in mathematics knows that *an arc is shorter than its tangent,* that is, that OP is shorter than OA; hence, logically, *the moon's velocity at* P *cannot possibly be as great as it was at* O, and by the same token she would not have sufficient momentum left to carry her in the succeeding second as far, either along the tangent or along the arc, as it did in the first. Unless, therefore, nature has some secret way of restoring to the moon this lost energy of motion so that her velocity is constantly whipt up and kept up, she must sink ever lower and lower, as any ordinary projectile would, and soon strike the earth. When, therefore, astronomers assert that the moon's "momentum" sustains her in her orbit, that her momentum is thereby nevertheless not impaired and that there is no way of renewing that momentum, they assert in effect that the whole minus many times its parts is still equal to the whole—that children can eat their pudding and have it too. So, indeed, they, can—*provided,* however, that new pudding be baked as fast as the supply on hand disappears; which is not shown to be the case here.

By way of an attempt to parry this difficulty, Newtonians have succeeded in persuading themselves that mathematical exactness between the velocity of the tangential motion and the force of gravity is not vital to the practicability of their conception. They tell us, with every show of confidence in their words and manner, that if the velocity bears to gravity a certain ratio, the resulting orbit will be a circle; that if this velocity be exceeded, the orbit will be a parabola or hyperbola; and that if the velocity be deficient, the result will be an ellipse, broad or narrow, according to the degree of such deficiency; but that in no event can the circulating body fall in. To see the fallacy of this representation, you need only take an arc of any conic section you may choose, draw its tangent and the *radii vectores,* and then go through the same demonstration as given above. It seems to me too plain for denial, that if the velocity be too slow, gravity, in the first second, must inevitably pull the body within the line of the conic curve, and that, the arcs of *all* conics being shorter than their tangents, the velocity in the second second will be not only slower absolutely, but, relatively to the force of gravity, very much slower. To such a process there could be but one sequence—the body would fall in short order.

Newtonians are by no means oblivious to the insecurity of the ground they here occupy, so they have added, by way of an alternative or makeweight, the fiction that celestial motions are "persistent". This idea they have borrowed from the so-called doctrine of conservation of energy. They have come to realize that Newton was too modest in asking merely for the gift of rectilinear motions by way of capital on which to run his cosmic system, and so they have added, for the sake of expediency, this new notion. In other words, they have gratuitously substituted in the Newtonian vocabulary the word persistent for inertia, its antonym. Now, our *terrestrial* experience offers us not a single example of motion not plainly traceable to a definite physical cause; so, to mark the difference, and as a sort of honorary distinction, they call the one sort "celestial" mechanics and the other, "terrestrial", exactly traversing, as it were, Drummond's *Natural Law in the Spiritual World,* by showing that natural law does not even rise to the height of the *physical* heavens!

A little sober reflection ought to convince anyone that attempts to solve the problems of the cosmos by adopting in the outset a group of "laws" transcending, and even contradicting, human experience, and, with these as a base, trying to harmonize celestial phenomena in other respects interpreted by mundane standards—must prove abortive. Natural law is consistent with itself from the greatest to the least; pervert one part of it and you involve yourself in an endless maze of error. Were the matter less serious, it would be amusing to note the airs assumed by astronomers at having "discovered" this supposed departure of celestial from terrestrial mechanics—this inconsistency of Dame Nature, the chief offender of her sex. Thus, the late Miss Mary Agnes Clerke, the celebrated English astronomer (*Modern Cosmogonies*, p. 10) says naïvely: "Kepler's ignorance of the laws of motion precluded him from the conception of velocities persistent in themselves, and merely deflected from straight lines into curved paths by a constant central pull." Let us, if you please, look into this "conception of velocities persistent in themselves" before we decide whether to prefer to be ignorant with Kepler or wise with Miss Clerke and the rest of Newtonians.

As you, of course, know, the moon travels around our earth, not in a perfect circle, but in an ellipse; of which latter the earth occupies the focus. The long axis of this ellipse is called the major- and the shorter the minor axis. The difference in the length of the semi-major axis and the semi-minor is 1550, but the difference between the longest distance of the moon and its mean distance is, in round numbers, 14,000 miles, while the shortest distance, or when the moon is at perigee, is by even a larger amount smaller; the exact distances, according to Neison, being 252,972, 238,840, and 221,614 miles respectively. Now, there is one way, and but one, whereby you can divide this orbit into exactly similar halves (at the same time severing the earth in half) and that is, by slitting it along the line of the major axis. Along one of these semi-orbits, the moon, proceeding from her perigee to her apogee, constantly decreases her velocity; while along the other, on her return journey, she correspondingly increases it. Now, the doctrine of ''persistent velocities'' holds that, in coming inward, the moon is endowed with the occult property of gaining, not merely in velocity, but in *strength of persistency,* or, what is the same thing, centrifugal force; whereas, in going outward, the contrary is alleged to be the case. So you see that, not even satisfied with demanding both uncaused rectilinear motions and gratuitously persistent velocities, we are asked to concede, further, that this *persistency* is *variable;* nor that, merely, but *intelligently* so! Moreover, every planet, every satellite, every asteroid, every comet, every circulating body throughout the universe of matter, we are asked to believe, is blessed with a similar occult power, each with a *special* rectilinear velocity, and a *unique* rate of increase and diminution, to suit the mathematical elements of its individual orbit—and the exigencies of Newtonian theory.

Thus, after long and arduous beating about the bush the astronomers have come back to the same point from which they started, flushed with pride at being able to tell us the illuminating news that they have discovered: that the planets got started of themselves, that they maintain and vary their speed by virtue of some secret unfathomable power, and that, in short, the whole business is quite as inexplicable as we at first found it to be! How sad to think that Kepler had to die in his ''ignorance''!

Again, Newton concentrated his whole attention on the fact that the moon falls from her tangent a trifle of 1-19 inch per second, equivalent in a lunar month of 2,551, 400 seconds to scarcely two miles; but he and his followers pass over, with but scant attention, the vastly greater variation in her altitude above the earth as between perigee and apogee, when, in only one-half the elapsed time, she rises the enormous amount of some 31, 000 miles, or 130 feet per second as against the 1-19 inch that she falls by gravity!—and this in the very teeth of gravity! Later, on the return journey, she loses this again, falling, now, 30,000 times as fast as she falls by gravity, but by poor marksmanship, or something else less understandable, she misses the earth that is calling her, falls *around* it, and again away. As to the two miles she falls by gravity, they furthermore tell us, she doesn't fall this distance after all, because she comes no nearer!

It is one of the ludicrous fictions of astronomers that the moon, having once gotten started in her tangent, is continually falling *beyond the limits of the earth* and therefore can never actually alight, but must continue circulating round and round the planet indefinitely. At perigee, for instance, the moon's velocity, they say, is such that it shoots the body so far beyond the earth, and with such force, as to fire her clear out to apogee, where gravity finally regains the upper hand and compels her return. On this return journey, they proceed, the moon is so *strongly attracted toward the center* of gravity of the earth as to cause her to acquire thereby so much momental velocity as to enable her to foil the attraction to which she owes that velocity, and at perigee to swing clear of the snare! To see how well the principle works out in terrestrial practice, try it out with a ball attached to a rubber string and see whether the contraction of the elastic will let the ball play any such tricks—*without the flinging motion of your hand to aid.* The notion that the moon can fall *beyond* the earth is in itself very silly, for, wherever it may be in its orbit, *it is always over the very center of the earth* and is being incessantly drawn toward that point.

To "elucidate" this matter in a way "intelligible to non-mathematical minds," Dr. Newcomb, in his *Popular Astronomy* (p. 77) says:

> To the mathematician the passage from the gravitation of an apple to that of the moon is quite simple; but the non-mathematical reader may not, at first sight, see how the moon can be constantly falling towards the earth without ever becoming any nearer. The following illustration will make the matter clear: Any one can understand the law of falling bodies, by which a body falls sixteen feet the first second, three times that distance the next, five times the third, and so on. If, in place of falling, the body be projected horizontally, like a cannon-ball, for example, it will fall sixteen feet out of the straight line in which it

is projected during the first second, three times that distance the next, and so on, the same as if dropped from a state of rest. In Figure 2, annexed, let A B represent a portion of the curved surface of the earth, and A D a straight line horizontal at A, or the line along which an observer at A would sight if he set a small telescope in a horizontal position. Then, owing to the curvature of the earth, the surface will fall away from this line of sight at the rate of about eight inches in the first mile, twenty-four inches more in the second mile, and so on. In five miles the fall will amount to sixteen feet. In ten miles, in addition to this sixteen feet, three times that amount will be added, and so on, the law being the same with that of a falling body. Now, let A C be a high steep mountain, from the summit of which a cannon-ball is fired in the horizontal direction C E. The greater the velocity with which the shot is fired, the farther it will go before it reaches the ground. Suppose, at length, that we should fire it with a velocity of five miles a second, and that it should meet with no resistance from the air. Suppose *e* to be the point on the line five miles from C. Since it would reach this point in one second, it follows, from the law of falling bodies just cited, that it will have dropped sixteen feet below *e*. But we have just seen that the earth itself curves away sixteen feet at this distance. Hence, the shot is no nearer the earth than when it was fired. During the next second, while the ball would go to E, it would fall forty-eight feet more, or sixty-four feet in all. But here, again, the earth has still been rounding off, so the distance D B is sixty-four feet. Hence, the ball is still no nearer the earth than when it was fired, although it has been dropping away from the line in which it was fired exactly like a falling body. Moreover, meeting with no resistance, it is still going on with undiminished velocity; and, just as it has been falling for two seconds without getting any nearer the earth, so it can get no nearer in the third second, nor in the fourth, nor in any subsequent second; but the earth will constantly curve away as fast as the ball can drop. Thus the latter will pass clear round the earth, and come back to the first point C, from which it started, in the direction of the arrow, without any loss of velocity. The time of revolution will be about an hour and twenty-four minutes, and the ball will thus keep on revolving round the earth in this space of time. In other words, the ball will be a satellite of the earth, just like the moon, only much nearer, and revolving much faster.

Our next step is to extend gravitation to other bodies than the earth. The planets move around the sun as the moon does around the earth, and must, therefore, be acted on by a force directed towards the sun. This force can be no other than the gravitation of the sun itself. A very simple calculation from Kepler's third law shows that the force with which each planet

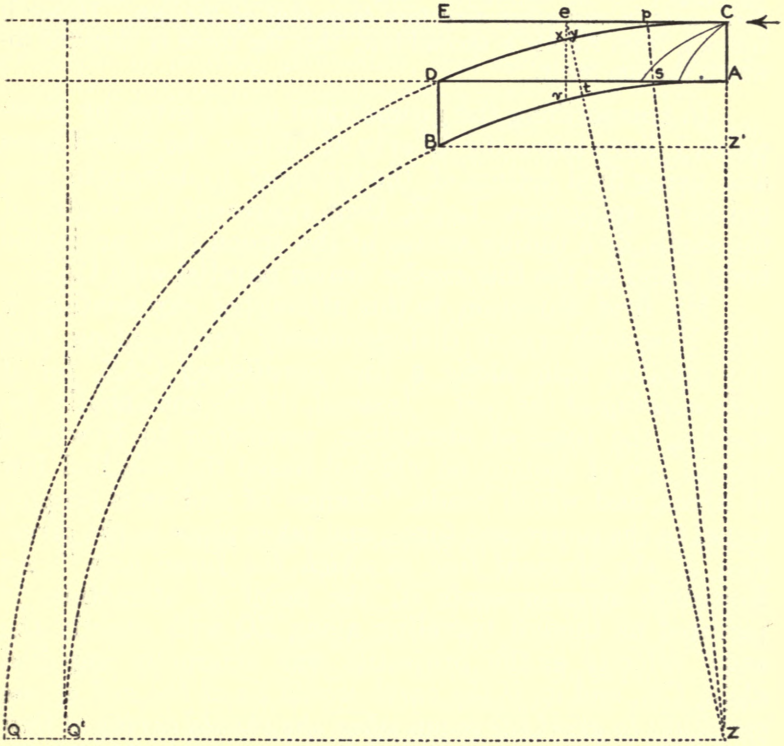
E
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Fig. 2

> thus gravitates towards the sun is inversely as the square of the mean distance of the planet.
>
> Only one more step is necessary. What sort of an orbit will a planet describe if acted on by a force directed towards the sun, and inversely as the square of the distance? A very simple demonstration will show that, no matter what the law of force, if it be constantly directed towards the sun, the radius-vector of the planet will sweep over equal areas in equal times. And, conversely, *it cannot sweep over equal areas in equal times if the force acts in any other direction than that of the sun.* Hence it follows, from Kepler's second law, that the force is directed towards the sun itself.

In transcribing the geometrical figure given by Newcomb, I have taken the liberty of adding the dotted lines and using final letters of the alphabet to designate new points of reference. Let Z, then, represent the center of the earth, *Ze* a radius vector of the moon (the projectile body), and let the line *exv* be drawn parallel with CAZ.

My first objection to this *attempted* explanation is that Newcomb errs in disingenuously representing that the satellite falls along a line *paralleling* CAZ, *for it does nothing of the sort.* Instead, it falls continually toward Z, the focus of attraction, according to Newton's second law of motion, on which is based the so-called law of areas, and which reads, "change of motion is proportional to the impressed force, and takes place *in the direction of the straight line in which the force acts.*" As Newcomb *mis*represents it, the point of attraction is pictured as though traveling along ZQ with exactly the same velocity as the projectile was originally impelled along CE, and *as if the earth would be at the end of the quadrant to greet the moon when she should arrive at that point.* Does he suppose the earth to have an astral body which it can thus project out of its physical corpus, and so prompt other cosmic bodies toward places where itself is not?

Plainly, the moon instead of dropping to *x,* therefore, falls to *y,* and we have a repetition of the condition exhibited in Fig. 1, in which it was shown that the velocity of the moon, by the combination of the projectile force with the centripetal attraction, is slowed proportionately to that of an arc as compared with its tangent. That the two forces mentioned do not act cumulatively, but in *opposition* to each other, resulting in a logical *diminution of speed*, clearly appears from the direction of the line *psZ*, which depicts the *mean* direction of the action of the central force, and which visibly intersects the tangent at an *acute* angle. This loss of velocity, be it noted, is *not* in any sense attributable to the presence of a resisting medium, but is the inevitable and logical outcome of the principle of central attraction, and *calls for the assignment of a substantial counteracting centrifugal force.*

Suppose, for the sake of argument, that the moon really *did* fall acceleratively as Newcomb describes, then at the end of the first quadrant she will have gained a velocity equal to 3350 feet per second *in addition to the "persistent" momentum* with which she started out. Would not this constitute quite an embarrassment of riches? Furthermore, what shall be said of the contradictory statements: that the moon only falls two miles during the entire month; that she doesn't fall at all, since she perennially preserves her mean altitude; that she falls out to apogee and in to perigee 31,000 miles alternately; and, finally, that she falls not uniformly but acceleratively?

Suppose that you were called upon to run a hundred yards against time, starting from scratch and thence *to and around a goal post* and return; do you think you could make as good a showing and with no greater expenditure of energy as in a straightaway course of the same length? Of course you couldn't; and you could not find a sane boy old enough to know what it means to run such a race who would say you could. Astronomers, however, tell us that the moon can! Every month she starts from perigee, runs her way out to aphelion, makes a wide detour, and returns to the starting point. At all points in her orbit 180 degrees apart, her compass direction is exactly reversed, showing that she must *arrest* all her motion eastward or westward, as the case may be, before she can *acquire a new* motion westward or eastward; yet month after month she has been doing this throughout the centuries, without, as alleged, drawing upon her stored energy to the extent of a single ounce, and without the loss of a shred of speed!

Again, we are told by our learned teachers that the reason the moon does not fall upon us is because of the fortunate circumstance that her motion is always directed *tangentially.* This, obviously, is a mere begging of the question. The point is, what *keeps* it thus directed? Imagine the earth and moon removed to outer space, where the attractions of the rest of the universe could not interfere, and started together at exactly the moon's present speed, along lines potentially parallel and 240,000 miles apart,—would, or would they not, gradually swerve from the parallels and within the space of a week's time, or thereabouts, collide? Of course they would, notwithstanding their having, by supposition, a double momentum to overcome, the earth's as well as the moon's. Manifestly, then, there is nothing in the abstract idea of tangentially directed motion to lift our problem beyond the reach of the legitimate effects of gravitational attraction.

Imagine, if you please, some marvelous bird as large as the moon, whose wings could take hold upon the ether as those of our terrestrial birds do on the air, to approach us out of the depth of space, and to take up its course in the wake of the moon at precisely the latter's velocity; and when the race was full on, imagine, further, a hunter to shoot the bird dead in full flight. Would the slain bird and the inanimate moon be subject alike to the same laws of matter, and should we then have two satellites in place of one? Would the bird, despite its death, not fall to the earth? Or could it fold its wings and still keep in the race? Would it, too, dead or alive, possess "persistent" motion?

Newton supposed that by argumentatively eliminating the resistance of the ether, postulating it to have existence but no body, he overcame the *only* obstacle to his inertial hypothesis. In this he was culpably in error. Take two pails precisely alike and provided with lids.

Fill one with sand, letting the other go empty, and carry them together for a furlong. Being exactly alike in size, they are, of course, equally resisted by the atmosphere. Which arm, however, will tire first, that carrying the full pail, or the other one? The former, by all means! The moon, too, *has a load resistance to overcome,* besides having to buffet the medium it traverses. We have already seen that this load amounts to the steady downward pull of 240 millions of millions of horses, more than a million times greater than the etheric resistance to the moon would amount to were that medium even as dense as our atmosphere at sea level. Talk about straining at gnats and swallowing camels! Returning again to the pails; would you say that by *running* the furlong instead of walking it, you would lessen the work done proportionally? Certainly not, and neither can the imaginary impulse that fired the moon on her course relieve her of the task of carrying her own dead weight. You cannot sophistrize gravity out of existence. To support the moon during the 29.5 days of her monthly journey from perigee to perigee and bring her back to the same altitude, she must from some *genuine* source—not from empty imagination or word-juggling—draw just as much lifting power as would be required to counteract the earth's gravitation did she possess no initial tangential translation whatever.

As suggested before in the introductory chapter, it has been the habit of those who make a study of the heavens, from time immemorial, to anticipate finding a good deal of mystery and miracle intermingled with prosaic fact. The supposition that nebulæ rotate of themselves is a modern example of this primitive instinct. So is the crude belief in the spontaneity of celestial motions in general, and in the inherence in them of persistency as an abstract quality. Perhaps, however, the most typical instance of this superstitious streak in modern astronomers is their conception of the significance of the *law of the conservation of moment of momentum.* By observation and computation, the astronomers have discovered the fact (for such it is, subject to a modification to be explained later on) that the sum of the momenta, axial and orbital together, of any given system remains the same from year to year. (Upon this rock it was that the Nebular Hypothesis met final shipwreck, but of this in a later chapter). They find, for example, that the planets, in their revolutions around the sun, do not follow their courses without regard to what the others are doing, but, on the contrary, rhythmically swing in and out from their aphelion to perihelion in such a way that, no matter where a *particular* planet may be in its orbit, whether going fast at perihelion or slow at aphelion, *the aggregate momentum of the group continues unchanged*: just as though there were an understanding among them, or as if they were controlled by some guiding hand. Now, astronomers do not make any pretense of understanding this mystery; all they know is that it is a *fact of observation.* Unfortunately, however, they presume to build upon it, construing it not as the manifestation of an unknown *physical* cause but as a sort of teleological ordination transcending natural law.

To illustrate how arbitrary and supernatural they conceive this law to be: Suppose, to take the case of the earth-moon system, we call the earth's axial momentum A, the moon's B, and the momentum of the moon's orbital motion C, then $A+B+C$ must always, under the "law", equal an invariable quantity M. Suppose, further, say they, that from any cause whatsoever (as, for instance, by colliding with a comet by a glancing stroke), the earth's rotation, A, should be greatly accelerated, then B and C, or one or other of them, would have to slow up correspondingly so that $A'+B'+C'$, the new values, might still be equal to M — not to M', but to M. On the other hand, they assert, that if the comet should hit the *moon,* sending her out fifty-thousand miles or so further, the earth would obediently rotate faster *of its own accord,* like a creature of sense, to make up for the moon's slower orbital motion, at the new distance! To the astronomer the phenomenon is an uncanny one, without rhyme or reason; a mystery as cryptic and capricious as luck at cards.

It is upon this abstract, metaphysical, arbitrary, ununderstood "law" that the world of science has erected its proudest generalization, the doctrine of the conservation of energy, *alias,* the persistence of force, correlation of forces, transmutation of energy, mechanical equivalents etc.—high sounding phrases that all alike decree the death of Nature. In the following pages I shall peremptorily challenge this doctrine as absurd and unworkable, and a mill-stone around the neck of Science. "Beware of him of whom all men speak well," exhorted the ancient seer. Beware, say I, of this doctrine of conservation which all the world extols. I expect to prove to you, dear reader, that this mysterious conservation of moment of momentum is as simple a physical phenomenon in essence as the rotating of a top; also, that the molar movements of the heavenly bodies are not accomplished without the expenditure of power, but with a power, GRAVITATION, that is at once creative and coördinating.

To sum up, the planetary theory of Newton holds, in effect: That the planets are revolving around the sun by reason of certain original rectilinear motions having miraculously belonged to them under some pre-existing order of nature; that they travel through a medium possessing objective existence without substance; that they can change their courses and bear loads without loss of momentum; that they have *fortuitously* happened to ally themselves to the same sun, to have hit upon approximately the same plane, to be traveling in the same direction, to have velocities bearing a fixed ratio to each other and to their solar distances, and finally, that after hundreds of millions of years no accidents have happened to any of them, by meteoric collisions or otherwise, to disturb this precarious arrangement. It neglects to take into account the factor of the stellar attractions, the sun's movement in space, the age of the sun and earth, or the rotation of nebulæ. It does not clinch the law of gravitation, or explain the moon's secular acceleration, or solve the problem of the tides, or account for meteors, or explain the relationship between comets, asteroids, and planets, or give the physical basis for the phenomenon of conservation of moment of momentum. It harnesses bullets with horses, and pits finite moments against creative gravity. It pretends that an arc is as long as its tangent, that the moon is falling to the earth's limb instead of toward its center, that persistent is a synonym for inertial, and that the whole minus an infinite number of times all its parts is still equal to itself.

Then why, you may ask, has the theory held sway so long? The answer is simple and lies in the nature of man himself, who finds in faith of some kind intellectual as well as religious repose. Just as many honest souls believe in this or that theological dogma under the mistaken conviction that denial thereof involves a denial of the Christian's God, so do men believe in this inertial theory under the hallucination that to deny it is to sacrifice the great cosmic principle of Gravitation itself. *My* system calls for no such sacrifice.

# III

# THE PRIME RESULTANT

LAPLACE was right in assuming that the numberless concordances exhibited in our planetary system cannot be the results of blind chance. So far as the principles of the Newtonian system go, the planets are restricted only to orbits having the form of conic sections. These orbits might be as elongated as those of comets, or as inclined as the earth's axis, or possess any other eccentricity or tilt you please. Some might revolve clockwise, others contra-clockwise, others, still, straight up and down, backward or forward, through the celestial poles, for all the light Newtonian theories throw upon the matter. The fact, therefore that the planets do *not* revolve thus indiscriminately, but conspicuously seek the same plane, revolve in the same direction, rotate on their axes in the same sense, and describe near-circle orbits, is decidedly too striking and significant to be dismissed as mere coincidence, and demands more than a teleological explanation. Indeed, what safe confidence can be placed in any cosmic theory that fails, as Newton's confessedly does, to clear up these remarkable concordances as one of its primary tasks and tests?

It is as plain as the noonday sun that the explanation we are groping for is a dynamical one; one, too, sufficiently comprehensive and general to compass in its mighty grasp the whole length and breadth of the system, so as to ensure that the effects it brings about may be universally consistent. The new factor, moreover, must allow as well for the *exceptions* to the general rule: it must be able to account, differentially, for the elongated orbits of comets as satisfactorily as for the rotundity of those of the planets; for the high inclinations of the asteroidal orbits as for the narrowness of the zodiac; for the rare cases of retrograde motion as for the vastly more numerous direct. On top of all this, the force we are in search of must not be speculative and imaginary, but substantial and of proven worth; and it must conform to all the facts. In a word, the motive power we are seeking is no other than an extraneous source of GRAVITATION.

Doubtless the reader is familiar with the phenomenon of the miniature whirlpool that forms on the surface of a basin of water while escaping through a central outlet in the bottom. Next the circumference the rotation, as you know, is relatively slow, but it increases rapidly toward the center, where often a hollow cone is formed round which the water revolves with high speed. Do you know the reason for this? It is because the equilibrium of the water, as a whole, is constantly being unsettled by the falling away of its support, and the act of gyration follows as an automatic effort at a general balancing. If the basin were very deep and the process sufficiently prolonged, you might perhaps find it worth while to investigate the law of gyration by sprinkling some sawdust on the surface and timing the turns at different distances from the axis of rotation. I can tell you the answer, namely, the cubes of the distances are as the squares of the periodic times.

This phenomenon has several curious counterparts in nature—in the ocean, in the atmosphere, and in the skies. Thus Sir John Murray (*The Ocean,* p. 198) says: "The Michael Sars Expedition of 1910 measured tidal currents in the open ocean down to a depth of 400 fathoms. It was found that the currents at 274 fathoms ran in the opposite direction to that of the upper layers which again approached that of the currents at much greater depths. At certain moments the currents appear to be arranged in the form of a spiral staircase, the whole system turning in clockwise direction from top to bottom." Again, Professor W. I. Milham in his standard work (*Meteorology,* p. 162), describes a similar peculiarity regarding the action of the atmospheric tides at the poles, even going so far as specifically to liken it to the "behavior of water in a wash-bowl while escaping through a central vent."

Now, if you will, slip on your wings of imagination and fly with me to a point in the heavens where we can obtain a good bird's eye view of our solar system spread broadside below us. But let us not view it, as customarily, from the north, but from the *south* side of the ecliptic, for there is a good reason which shall presently appear. Note the enormous size of the system. The sun in the focus is himself so huge that from his center to his circumference is almost 200,000 miles greater than from the earth to the moon. Yet that immense body, if viewed from Neptune, his outermost planet, 2,800,000,000 miles away, would barely show a disc to the naked eye. Suppose Uranus, whose distance is 1,800,000,000 miles, to be directly opposite Neptune, on the other side of the sun, and then imagine a giant sun big enough to fill in the gap from one planet to the other. Retire now in spirit to the distance of the *nearest* star, *Alpha Centauri,* some thirty million, million miles away, then will this giant sun of our imagination appear to you almost exactly of the same size as would the real sun to an inhabitant of Neptune!

We see then that, scattered as the members of our system may be, and minute as they are as compared with their separating distances, they are nevertheless next door neighbors when contrasted with the stars in general. It is because of this relative isolation that they are enabled to retain their identity as a group or unit. That they form a *real* unit or machine is sufficiently evident from many circumstances whose concerted evidence it is futile to gainsay; the vital problem being, to what extent are they allied and what are the terms of their confederation?

Now, we cannot master any subject thoroughly save by considering it in all its relations. A man may be at once a son, father, functionary, citizen, cosmopolite—each of which characters implies higher units of which he is but a fractional part. The question suggests itself; May not the solar system, also, be but a cog in a yet greater machine, and should it not be interpreted internally *as affected by externals?*

Gravitation I accept as an objective reality. I recognize the right of the reader to accept or reject it at his option, but unless he is willing to accept it in its broadest implications he may just as well stop here. If the force of gravitation extends from the moon to the earth, from the earth to the sun, and from the sun to Neptune, without sagging of the law, I contend there is no logical reason why it should not extend throughout the universe to its outermost limits. Moreover, if this be indeed true, you can no more solve the problems of our system, or of the earth alone, without taking this new relation into account than you can explain our change of seasons without mentioning the sun.

Suppose only two bodies to exist in space, at rest, and separated from each other by a finite distance, they would then inevitably approach each other in a direct line and finally meet. Supposing the law of equilibrium to apply, namely, that freely moving bodies seek their lowest center of gravity; the direction of the axes of the two bodies would in that case point each other out in the sky until they met. Suppose, now, we add a third body and call them A, B and C, all of the same size, starting from rest, and so placed as to mark the points of an equilateral triangle. In this case the axes of the bodies would *not* point to each other, but would instead aim at the blank point being the mathematical center of the triangle, where eventually they would all simultaneously collide.

Now, we do not live in a universe of two or three bodies, but in one of many millions; not in one of two dimensions, but of three. Moreover, the planet we live on is pointing to *something* with its axis. To what, then, if not to the mathematical point to which the stars with their *resultant* attraction are drawing us? Here you may interject that this cannot be true, because if the earth be indeed so falling, it is falling in vacuo and that bodies so falling do not obey the general law of equilibrium. I shall answer this objection squarely in a future chapter.

Assuming, then, for the time being at least, that the law of equilibrium is too precious to be cast aside without a struggle to preserve it, you may ask next, "How can we tell whether the earth is falling north or south?" I answer, by contemplation of the earth itself. Many attempts have been made from time to time to explain the great preponderance of continents in our northern hemisphere and their pronounced tendency to cluster around the north pole. No one needs to be told that rock is heavier than water, and where the contest is for the lowest place, the weightier substance will sink and cause the level of the lighter, liquid, to rise. Consider, also, that the longer a cause continues, the more its effects accumulate and thrust themselves into evidence. The earth has demonstrably been suspended over the abyss of space for millions of years, until, as in the case of a floral hanging-basket, its crust has, so to speak, protruded downward through the meshes. After this manner it is that mountain ranges are formed on so huge a scale. Like cakes of ice jamming against a pier, the hinder continents, or, often, the ocean beds grown irresistibly ponderous by the sedimentary accumulations of ages, press or lurch heavily forward, not only relegating the oceans to the rear (south), but crowding the land masses in front, bending, jamming, wrecking and crumpling them until, for the time being, further progress becomes stalled. Thus the earth's crust moves in gigantic billows and alternately rises above and sinks below the level of the sea. Most certainly, then, the northern hemisphere is the *heavier,* hence the *under,* and the earth is falling in the line of its axis northwardly. Logically, therefore, our school maps should be inverted, and it is my opinion that had they been hitherto so printed, this discovery would years ago have been anticipated. The Arctic regions are not the *roof* of the world, as they are often called, but the *bottom* of it.

It has long been one of the primary puzzles of geology as to why mountain ranges seemingly wait to be lifted up until the sedimentary rocks, of which they are mostly formed, attain their maximum thickness. Professor Joly, for instance (*Radioactivity and Geology,* p. 97), quotes Dana approvingly as follows:

> A mountain range of the common type like that to which the Appalachians belong is made out of the sedimentary formation of a long preceding era; beds that were laid down conformably, and in succession, until they had reached the needed thickness; beds spreading over a region tens of thousands of square miles in area. The region over which sedimentary formations were in progress in order to make finally the Appalachian range reached from New York to Alabama and had a breadth of 100 to 200 miles, and the pile of horizontal beds along the middle was 40,000 feet in depth. The pile from the Wahsatch Mountains was 60,000 feet thick, according to King. The beds of the Appalachians were not laid down in a deep ocean, but in shallow waters where a gradual subsidence was in progress, and they at last, when ready for the genesis, lay in a trough 40,000 feet deep, filling the trough to the brim. It thus appears that epochs of mountain making have occurred only after intervals of quiet in the history of a continent. * * * Nor would the list of such crustal movements be complete save in the enumeration of every great range upon the earth.

Plainly, then, the formation of great mountain chains is analogous to the action of condensed moisture on the outside of an ice-cold pitcher. For a second or so, a small drop, after coursing down an inch or two, will often stop dead, held in its place by adhesion, until, being reinforced by a fresh drop following in its track, it will again start downward, perhaps to stop a second time and repeat the performance before attaining the bottom. So, before a mountain range can be lifted into place, a great dynamical agency must be *accumulated* for the work in hand. This Nature does gradually by laying one stratum upon the other on the bed of the ocean and incidentally eroding away the obstructing land in front out of which to form those strata, until the weaker becomes the stronger, or the lighter the heavier, and crowds its way onward toward the "bottom". Of course this process is exceedingly slow, and its results are normally very gradual, the strata bending rather than fracturing; but by no means is this always the case, for sudden slips are here just as bound to occur as landslips at the Panama Canal or iceslips in the Alpine glaciers. I should like very much to pursue this principle further into its many geographical, geological and biological ramifications, but it would lead us too far afield, and, besides, would require several times the size of this work for its proper presentment. The learned geographer, if he but once master the faculty of viewing things in their obvious aspects and relations instead of through the blurred and billowy spectacles of Authority, can in an hour's time reconstruct all he knows of these three subjects into a correlated system. The main key lies in this fact, that the earth's general form, its topography, and its continental distribution and configuration, are determined by a tri-dimensional gravitational scheme, namely, (1) by the *point* of attraction connoted by its own center of gravity, whose endeavor it is to mould the planet into a perfect sphere; (2) by the *plane* of attraction, to-wit, the influence of the other members of the solar system, whose function it is to produce the tides in atmosphere and ocean, etc., and (3) by the third dynamical dimension, completing the "*solid*", being the joint or composite attraction of the outside universe that compels the earth, under the fundamental law of equilibrium, to keep lowering her center of gravity more and more by precipitating her heavier surface substances north-pole-ward. These three influences, then, all operating simultaneously, cannot but result in a deformation of the general contour of the earth; producing, as the most important effects besides those mentioned, the squashing or flattening of the earth, the raising up of the equatorial protuberance, the special flattening of the northern hemisphere, and the relative arching of the southern, all of which, indeed, seem to be objective facts. It has recently been established that the Antarctic continent has in time past been, and is to-day, submerged in large part. This is to be expected, for, being on top, it cannot easily slip off to one side, but must sink in; like a hat on one's head it sits firmly when worn straight, but it is apt to fall off if carelessly tilted. On the other hand, the presence of an Arctic ocean close around the pole is equally to be expected, the continents having become wedged against each other before actually attaining the goal, and forming a protecting shoulder.

In earlier eons, the migration of the continents northwardly was doubtless much faster, relatively, than it is to-day, for now they have become jammed, and hence much longer accumulations of depositions must precede every infinitesimal advance. Have you ever wondered how the Esquimaux came to settle in the Arctic wilds? Have you never marveled at the highly organized forms of life that inhabit those inhospitable regions? Do you think such life as that can have *evolved* there from primordial forms? No! There is only one explanation that will serve, and that is, that the land which they and their forebears have inhabited from paleolithic days on, has not been the immovable platform for which they have all along mistaken it, but a land raft that imperceptibly has carried them through genial climates and latitudes to where they now find themselves. But this is not to be a work on biology, so let us return to the main theme.

Before proceeding to the more general problems of the solar system, let me emphatically warn the reader against inferring that the axis of the earth is pointing to the *center of the universe.* I do not mean to convey any such impression. An apple falling from the twig of the tree where you may be sitting as you read this, and one falling at the same time in the antipodes, though in absolute space moving in opposite directions, are really tending toward the same point, namely, the earth's center of gravity. But no one would think of arguing from this that the earth's center is therefore the center of the universe! Mass for mass, proximate bodies dictate much more strongly than those more remote the course a celestial orb shall follow, and no two bodies are affected by the sum of attractions to the same extent, or impelled toward the same mathematical point in space. We know, furthermore, that all of the stars are in rapid movement, not only absolutely but relatively, for which reason the goal or focus of the attracting powers is forever rhythmically shifting about. When I assert, therefore, that the earth is headed toward a *blank* point in the heavens, I mean that the merging of all the attractions focussed upon her unite to coerce her movement, not only in a definite line but also to and through a definite, unmarked, mathematical point in that line. This line I call the Prime Resultant, and this point, the Vertex, which latter, in the present case, coincides with the dynamical (not the *celestial*) pole of the ecliptic. The Vertex, then, may be described as the hub or localized center of attraction for our particular planetary system, just as the earth's center is for all objects within, say, her atmospheric envelope. To make the matter perhaps still clearer, consult again the example of the three bodies, A, B, and C, which we assumed to be arranged in the form of an equilateral triangle. There the center of the triangle is the "vertex" or converging point for all three bodies, and the distance from that point to either of the three severally is the prime resultant for that one particular body.

Let us return now to the position we originally occupied, directly over and far *south* of the sun, and looking straight down on the broad plan of the solar system, and let us suppose that we remain thus fixed in space so that we may the better analyze the movements of the group. It is customary with astronomers, repeating, in their way, the awkward method of geographers, to imagine themselves surveying the ecliptic from the north. According to their way of looking, the motions of the earth on its axis, of the planets around the sun, and of the moon around the earth, are all contra-clockwise (like a clock dial reflected from a mirror), whereas viewed from the south, as I advise, those motions all turn clockwise. It is well to get clearly in mind right at the very outset the fact that all of these motions *run in the same direction.* This is the rule throughout the system (with a very few minor exceptions among the satellites, which will be subsequently considered).

My object in viewing the ecliptic from the south instead of from the north is, however, of much greater significance than merely to aid the memory by substituting a right-handed motion in place of a left-handed one. In fact, it is for the same reason that I recommend the printing of terrestrial maps inverted, namely, to instill and cultivate the sense that we are *falling,* and that *north* *means down.* I wish the reader to realize as vividly as possible that in surveying our system from a point south of it he is looking *down* on the action of a whirlpool, physically as real as the surface of water emptying from a wash-bowl. Due to the suction of the Prime Resultant, the weight is constantly slipping away, more at the center than elsewhere, necessitating continuous readjustment of the systemal balance. Due to its mobility and molecular attraction, the water in the basin reacts as a unit to central suction, and, in the same manner, the movability of the planets and their mutual gravitational attractions enable them to constitute themselves into a gravitational unit and sub-units, with similar power to readjust their common balance by a process which may be described as one of *progressive equilibrium.* There is the great whirlpool embracing the system as a whole, and there are also the eddies within it of Jupiter and his satellites, Saturn and his rings, and the rest. Or, if you like, you may think of our system as a prodigious clock, without visible springs, pinions, or hands, and with mere points to mark the various divisions of time, being driven by the force of its own fall. As the earth is a simple body conforming to the law of lowest center, so the earth and moon together form a *compound body* seeking their lowest *common* center of gravity, and so, too, do the sun and all the planets and their retinues summed together constitute a *complex body,* riding upon one common center of gravity. Where does the series end, or has it an end? May not our system be but a member of a system next greater, that of another larger still, and so on up to star-streams and the great whirling tire of the Milky Way itself, welding the entire universe, be it finite or infinite, into a single correlated Whole, all under the unifying, organic law of BALANCE?

Now, with this key in hand, let us resurrect the difficulties which confronted us before. Take the instance of the earth and moon; what keeps them apart? As I stated before, no two bodies in the universe are attracted precisely with the same force nor to identically the same point in space. Follow, if you please, that ray of the

Prime Resultant that extends from the center of gravity of the moon to the Vertex, also that ray from the earth's center of gravity to the same point. You will now, I hope, be able to perceive that the Vertex is not the simple mathematical point it may have seemed at first blush, but a PLEXUS OF MANY STRESSES. In a general sense, our whole solar system has indeed the same Vertex, but to that Vertex each individual particle and molecule is attached by its own independent strand. Between these strands there is in every case a minute jog, or angle. In fact, the strands all cross each other at diverse, though proximate, points and lead away beyond the Vertex. Moreover, they can by no possibility ever fully unwind, though always unwinding. To illustrate: Take a yard stick and from its ends pass tethers through a ring letting them extend a little beyond, being careful to see that they are crossed where they pass through the ring. Now pull the tips of the strings and you will find there is a torsion on the stick tending to turn it around its axis, which torsion will cease only when the strings no longer cross. As I said before, in the case of the earth and moon (as a typical example), their gravitational filaments to the Vertex stay crossed and are always "wound up", unceasingly twisting the two bodies round and round each other; the rigidity of the stick being replaced by the momentum implanted in the bodies by their cosmic fall. And so throughout the system and the universe.

Thus you may see that the "centrifugal force" of the moon is a *real* thing, and I hope, too, that you perceive that it and the centripetal attraction of the earth adjust themselves to one another automatically; which means, to perfection. Our old equation, then, may be amended thus:

$$M-C+C'=M'$$

in which $C$ and $C'$ are immense real quantities of a creative nature, but cancel each other, in the shape of work done, leaving $M'$ continuously equal to $M$. Incidentally, it may be affirmed that the moon does not fall, in any fair sense. The true explanation is, that between the centrifugal motion maintained by the Prime Resultant and the centripetal attraction of the earth, there is a constant equality. We have hitched two horses together of equal strength and pace, to team the moon and the planets around their several courses.

There is, however, a slight modification of this principle that must be taken into account; slight in amount, but vitally important theoretically. It is this: The Prime Resultant, being gravitational in character, such movement as it gives rise to is a *falling* movement, consequently *accelerating.* The moon, therefore, should logically be revolving around the earth faster and faster in accordance with the well-known law that *the advance of a falling body increases with the square of the time.* Harken now to this passage from Young (*Gen'l Astr.* p. 301), and note the italicized words; the italics being his own:

> There remains one lunar irregularity among the multitude of lesser ones, which is of great interest theoretically, and is still a bone of contention among mathematical astronomers, namely, the secular acceleration of the moon's mean motion. It was found by Halley, early in the last century, by a comparison of ancient with modern eclipses, that the month is certainly shorter than it was in the days of Ptolemy, and that the shortening has been progressive, apparently going on continuously ° ° ° ° In 100 years the moon, according to the results of Laplace, gets in advance of its mean place about 10″, and *the advance increases with the square of the time!*

This vexed question of the acceleration of the moon has, since the time of Newton, commanded the life efforts of some of the best mathematicians the world has produced, always with one goal in mind, namely, TO SMOOTH IT OUT AND CAUSE IT TO DISAPPEAR. It seems never to have occurred to any of them, any more than to the Ptolemaists struggling with their seventieth refractory epicycle, that ITS VERY REFUSAL TO IRON OUT IS A SIGNIFICANT FACT DIRECTING ATTENTION TO SOME FUNDAMENTAL ERROR. An idea of the enormous amount of labor involved in this mathematical problem, known among astronomers as "the theory of the moon", may be gained from this statement of Professor Ernest W. Brown, the latest, and now recognized as our highest, authority on this particular matter:

> Mr. Sterner and I in our investigation of the theory of the moon's motion, have probably occupied altogether about 8 or 9000 hours. There were about 13,000 multiplications of series made, containing some 400,000 separate products; the whole of the work required the writing of between 4 and 5 million of digits and plus and minus signs. Although the problem now completed constitutes by far the longer part of the whole, much remains to be done before it is advisable to proceed to the construction of the tables.

Here, then, is the practical solution of this vexed problem (incidentally, also, of Mercury's perihelion anomaly), a solution that restores to us the law of the inverse square pure and undefiled. Now, I do not assert that computers can hereafter discard the minute Newcombian decimal, of which I have previously spoken, and get the correct answers notwithstanding. By no means! What I claim to do is to explain the *origin* and *justify the use* of the decimal and, its significance being recognized, to *construct the science so as to conform.* Kepler and Newton were both wrong, and the astronomers of to-day are wrong, in declaring that the planets revolve *per principium* in conic sections; *they revolve in conic spirals.* This, then, is what I had in mind when I asserted in the Introduction that the minute decimal referred to could be eliminated only *by the complete overturning of the Newtonian system*!

If I am, in very truth, correct in the hypothesis that the solar system is gyrating as the natural result of a continuous struggle for equilibrium against the unsettling suction of the Prime Resultant, then the following conclusions follow as plain matters of course:

1. That such equilibrium can be maintained only by steady rotation of its members *in the same direction.*

2. That *circularity of orbits* is the natural evolution of this process.

3. That the *stablest* form into which a body can be fashioned is, gravitationally speaking, the *flattest* form;

because the center of gravity is then depressed the lowest possible. The planets, for this reason, in the pursuit of their general equilibrium, affect, very closely, *the same plane of rotation around the sun.* So near are they to one plane, indeed, that, reduced to a small enough scale, the system would practically fit into a box about the shape of a silver dollar.

4. That what can be truthfully said of the planets in these respects applies with no less force to the subordinate systems and to the *axial* rotations of the planets.

Thus does the introduction of the Prime Resultant into astronomical theory justify its entrance by explaining, *dynamically,* all those numerous and amazing concordances that Laplace sought to explain by postulating the monstrosity of a self-rotating nebula. Indeed, it explains the rotation of *all* the nebulæ just as effectively, for these, too, are gravitational units. So are many of the star clusters. Even the Milky Way itself is a gravitational unit, composed though it is of billions of separate stars, seeking its equilibrium with respect to the stellar resultant playing upon it from many distant universes like it, so far distant, indeed, that their light dies out before it can reach us. The facts are not susceptible of observational proof, but to my vision the Galaxy is nothing else than a disc of starry globes extending indefinitely beyond our keenest telescope, and revolving, like our solar system, about an axis passing through its poles.

## RETROGRADE MOTIONS

"But what about the *retrograde* motions?" I seem to hear asked. These may be generally divided into two classes: those of asteroids, and those of satellites.

The first of these classes involves the solution of the nature and origin of the comets. These bodies, as I shall later explain more fully, are fragments cast off by exploded stars and enter our system as fugitives from their own land seeking an asylum in ours. When they first make their appearance, they exhibit certain eccentricities that proclaim them at once as strangers. For one thing, their orbits are very elongated, with diverse inclinations, and, for another, they are just as likely to have retrograde as direct rotations. It goes without saying that such erratic visitors cannot fail to disturb the balance of our system to some extent, and themselves be reacted upon in turn; just as the throwing of a basin of water into the sea theoretically affects the general level and the mutual relations of all the drops in it. From the instant of its haphazard injection into our system, the comet feels the influence of the gravitational current or whirlpool in which the planets are rotating, and immediately begins the process of accommodating itself to the balanced order of our system. This process is vastly prolonged, but it is sure and steady, and it results finally in rounding out the comet's orbit, in reducing its inclination, and often in converting its retrograde motion, if such it had at the start, into a direct one. In short, the alien becomes a full-fledged citizen. Thus I deduce that many (not all) of the *asteroids are simply domesticated comets*, and that their departure from planetary regularity in the matters of retrogression and orbital eccentricity and inclination are just so many survivals of their preceding cometary phase, which time will largely wear away.

There is, however, a second cause for retrograde motions, and this applies more particularly to *satellites*. The three or four instances among these bodies exhibiting this peculiarity, it will be remembered, are the *outermost* members of their respective systems. Now, between the eddy of Saturn's group and that of the Jovian group, for example, there is a point or line where the circumference of the eddies may be supposed to impinge or "interfere," whirling there *in opposite directions*. This region, however, is not a well defined line but a rather nebulous zone, so that a body which for any reason has become entangled in it halts, as it were, between two allegiances, undecided whether to attach itself finally to Saturn's system or to Jupiter's. The result is, obviously, a mixed or hybrid motion whose analysis will require the methods of higher mathematics to reduce to definite terms in individual cases. For the present purposes, it is sufficient to characterize the effect as that of a "back eddy" in this complex gravitational whirlpool of ours.

Here, too, we have the complete physical explanation of the conservation of the moment of momentum, which, as shown in the preceding chapter, has heretofore been explained teleogically. The Prime Resultant is, as everyone can readily perceive, a *physical* force that compasses the entire system, so that all changes of momentum are accelerated throughout in like degree, thus all but concealing the *fact* of change. In other words, the yardstick with which we here measure shrinks and expands synchronously and commensurately with what it is employed to measure. The conservation theory is consequently not correct in the abstract sense. Our planetary system *is* altering its aggregate momentum, in keeping with the acceleration of its cosmic fall.

Descartes was right in diagnosing the gyrations of our system as *vortical* in principle, but he failed to establish the fact because he reasoned without universal gravitation.

## THE PRECESSION OF THE EQUINOXES

In explaining the cause of the seasons, the books ordinarily speak of the earth's axis as remaining constantly parallel to itself, thus tilting the north pole toward the sun in summer and hiding it from him in the winter. This explanation suffices for beginners in the study of the science, but more advanced pupils are taught that the axis does *not* remain absolutely parallel, but revolves around like the axis of a common top when it is just getting ready to fall over. This movement in the earth's case is exceedingly slow, requiring almost two hundred and sixty centuries to complete it! The way astronomers originally discovered this fact was by noting the times of the recurrences of the vernal equinox. This has since been established to arrive about 20 m. 23 s. earlier each succeeding event, making what is known as our tropical (weather) year that much shorter than the sidereal one.

But there is another way to measure this change, namely, by the length of arc described, and this amounts to 50.2″ per annum. This circle of revolution can be and has been mapped upon the celestial sphere, or at least a considerable arc of it has been, from data which have come down to us through the past 3,000 or 4,000 years. Imagine the axis of the earth extended northwardly to the farthest sky, then the point of it, which now lies near the pole star, does not rest permanently in one spot, but travels anti-clockwise around a central point, called by astronomers the pole of the ecliptic, but which is not marked by any star. The radius of that circle (mark the extraordinary coincidence) is 23½°, which is *just exactly the inclination of the earth's axis!* What is even more remarkable is, that in all my reading I have never found this curious fact alluded to, just as though coincidences such as this were quite the normal thing. Nor has any astronomer, as far as I am aware, ever attempted to investigate the marvel! Yet its cosmic significance is crucial.

Newton, groping in the dark, as I have already described, undertook to explain the *fact,* but not the *coincidence.* The phenomenon is known as the *precession of the equinoxes.* Newton's explanation may be thus stated: The equatorial radius of the earth exceeds the polar by about 13 miles, consequently there is a great ring of excess matter belting the planet and rotating obliquely with respect to the ecliptic. If this belt were in the form of a satellite, he reasoned, it would rotate around the earth agreeably to the same principles of rotation as the moon, and its orbit should therefore have nodes and exhibit a precessional movement of those nodes. But the ring, he went on, is *not* a satellite, but, on the contrary, is firmly affixed to the planet, consequently its natural nodal motion of rotation, being unable to express itself otherwise, must react upon the earth itself and cause a wobbling of that body's axis, technically called *nutation.* The tendency of the nodes to regress he found to arise from the fact, in the case of the moon, that that body is continually shifting from one side of the ecliptic to the other, and that the sun's attraction upon it is forever, though vainly, trying to bring it into the plane of the ecliptic, a condition that is no less true of the equatorial protuberance.

### *Newton's Precession Theory Denied*

Now, the earth rotates on its axis once daily, thus bringing every inch of its equatorial bulge fairly under the sun's attractive influence. The *cycle of causation* is complete, why should not the *cycle of effect* be, also? Can you think of any sound reason why the earth's axis, if it is affected at all by this operation, should not make *daily* a *complete* circle of nutation, however minute, rather than the 1-365 part of the 1-26,000 part of a big circle? Again, the earth revolves around the sun in 365 days, presenting the equator in like manner to the sun's attractive influence at every angle of her axial inclination. Here the *annual* cycle of causation is complete, why should not its cycle of effect be *annually complete* also? Why, indeed, should 26,000 complete cycles of causation, for no intelligible reason, save themselves up to make one big circle instead of 26,000 sucessive minute ones, and why, indeed, should the radius of that peculiarly generated big circle be so amazingly identical with the earth's axial inclination? What would you say of a man who, in cool deliberation, would protest that 9,490,000 of our days and nights (26,000 of our summers and winters) should yield us a *single* day of daylight 13,000 years long and a single night of 13,000 years? Yet thus, in effect, is how Newton reasoned in this case.

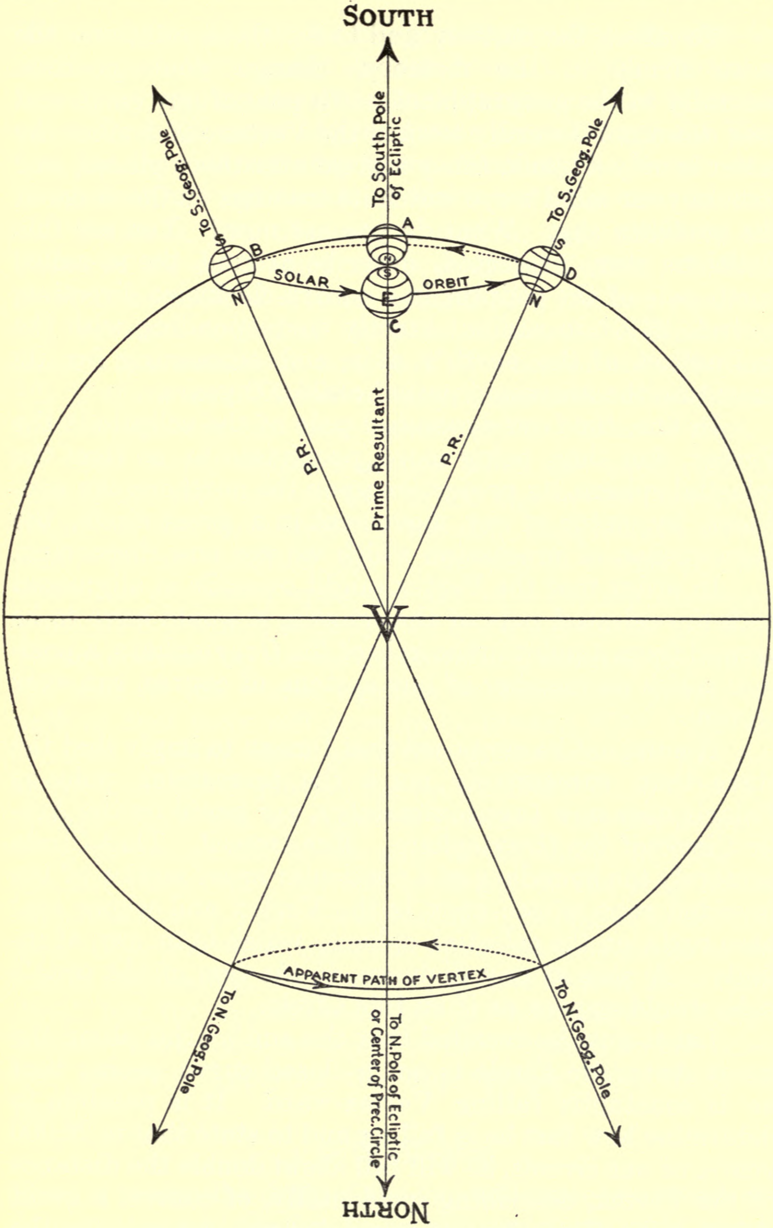
### THE TRUE CAUSE OF PRECESSION

Every action has its equal and opposite reaction. This is not only Newton's second law, but it is likewise the fundamental principle of the *gyroscope.* The solar system, therefore, must, of necessity, recoil backward as a unit by way of compensating for its general forward gyration around its own axis, the sun. The next questions then to arise are: Does the solar system recoil in a straight line, or in a curve? Why? and In what kind of a curve? To begin with, in order that the system may recoil at all, it cannot possibly abide in one place, but must keep perpetually on the move. Nor can it sail away in a straight line, because, by premiss, it is tethered to the local centrum or Vertex of stellar attractions, hence a reëntering curve must consequently result. But here, again, we are confronted with the circumstance that the system is *falling at the same time,* hence our *final* conclusion must be that the center of mass of our system is pursuing a sweeping *spiral* path, inferentially requiring some 26,000 years to complete a single *coil* of it.

In order to make all these relations perfectly clear in the reader's mind, let us, for the time being, disregard the falling motion of the sun and treat his path as a simple closed curve. Imagine then, if you please, an immense sphere suspended in space, having for its center the Vertex and for its radius the stem of the Prime Resultant (that is to say, the distance between the Vertex and the *sun's* center), and for convenience of reference we shall call it the *Gravisphere.* For reasons previously stated, let us picture this sphere as inverted, with its south pole at the top, and inscribed on it an Equator, and Arctic and Antarctic circles. Transport yourself now, in spirit, to the Vertex and, from it look *up* at our descending system and take note of its motions, imagining yourself to continue in the same position for 260 centuries. This is what you should see: first, a complete revolution of the system in a *clockwise* direction around the line of the grav-Antarctic circle which, being projected against the celestial sphere, would describe on it precisely the same sort of circle, around the southern pole of the ecliptic, 23½° in radius; second, you should see the north pole of the earth's axis constantly turned toward you, so steadily, indeed, that were that axis a hollow bore you could see clear through it, at all times, to the background of the southern sky beyond; third, you should see the earth rotate on its axis in a contra-clockwise direction; and, fourth, you should see all the planets revolve around the sun, and the moon around the earth, in this same left-handed manner. (See Fig. 3.)

## THE GRAVISPHERE

EXPLANATION:—This is an imaginary figure designed to portray the relation of our solar system to the universe at large. Observe that the *south* pole is placed at the top; this has been done purposely in order to impress the lesson that our cosmic *fall* is toward the *north* celestial pole. It has been found desirable, for the sake of avoiding confusion, to represent the Gravisphere as stationary and the orbit of the sun (along the Antarctic Circle) as closed; but the reader should conceive of the whole Sphere as falling the length of its own diameter (3,836,000,000,000) in the period of some 20,630 years. The arrow-heads in the line of the Circle indicate the direction in which the sun is moving; but were it correctly represented, the path should actually appear as a deep spiral coil with a sheer fall equal to its horizontal circumference and a total length of 6,800,000,000,000 miles. The Prime Resultant is shown in three different positions, but in reality it follows the sun's movement, describing the cone that has the Antarctic Circle for its base. The earth is drawn (vastly enlarged in proportion) in four different quadrantal positions, 6,452 years apart, in order to exhibit the nutation of its axis whereby the Circle of Precession is produced. In parenthesis, it may be added that the center of the Gravisphere (the Vertex) does not fall in a perfectly rectilinear path, but in a curve whose radius is on the order of 10 light years and period of revolution 1,900,000 years.


SOUTH
To South Pole of Ecliptic
To S. Geog. Pole
To S. Geog. Pole
A
B
C
D
E
S
N
SOLAR
ORBIT
P.R.
Prime Resultant
P.R.
V
APPARENT PATH OF VERTEX
To N. Geog. Pole
To N. Pole of Ecliptic or Center of Prec. Circle
To N. Geog. Pole
NORTH

THE GRAVISPHERE
Fig. 3

To check the matter, and to fix these relations the more firmly in the memory, change your position mentally to the geographical north pole of our earth and look down northwardly toward the Vertex; and, since the latter is only a blank, fancy a great star there placed, and then in your mind's eye watch its tracings on the dome of the *northern* sky. What do you see now? You see this fictitious star, projected, describe around the so-called north pole of the ecliptic, in a contra-clockwise direction, a circle 23½° in radius; exactly corresponding with the inclination of the earth's axis, and consuming for its execution the aforesaid period of 26,000 years.

In fine, the true *dynamical* pole of the ecliptic is the Vertex, but this, being more proximate to us than the celestial sphere, its *projection* upon the northern sky produces, by virtue of *our* movement in a great circle, the phenomenon of precession which we are now discussing.

In order that the Vertex might *coincide* in alignment with the celestial pole of the ecliptic, it would have to be viewed from a point inthe axis of the Gravisphere, a position which no member of our system, of course, can ever occupy.

It must not be supposed that I mean to imply that the stars that successively mark the terrestrial pole as Polaris does now (approximately), are posed *on* the Arctic Circle of the Gravisphere. Far from it. That Circle is merely the boundary of a particular cross section of the inverted cone whose apex is the Vertex and whose real base rests on the celestial sphere, which is to say, at infinity. A star at any distance, *in the line of the cone's side,* would appear as if on this Circle.

Let it now be recalled that the sun's orbit along the great Antarctic Circle is *not* a closed curve, seeing that he is constantly falling Vertex-ward. It is possible to determine how fast he is falling and to state that in 26,000 years, or one circuit, he will fall about double the distance of the Vertex, describing incidentally, of course, a great spiral coil. This, however, need alarm no one, for the simple reason that the Vertex is a kind of will-o'-the-wisp. You cannot imagine a point in space where a body, if there placed, will not be gravitationally directed toward some *other* point distant from it. Our Vertex is merely a stepping stone to our exploration of the infinities around us. The rays of gravitation pass through the Vertex, but they do not stop there. Besides, the Vertex is a blank spot and not a rock on which our ship can founder.

There is, you observe, no central sun, either in the center of the sun's orbit, nor even at the Vertex. Indeed, there is no need of a great central sun, for two reasons; (1) because, as I shall show later, stars are limited by nature to a maximum size, just like men or animals; and (2) if stars could grow to any magnitude whatsoever, they would long ago have put an end to Nature's plan.

The vernal equinox occurs when the earth, and of course the sun, are on the exact line of the Antarctic Circle of the Gravisphere, the sun then always in the rear. At one position, say A, the sun at vernal equinox would be projected upon the sky in a certain direction, while, at B it would be projected one quadrant to the *west*. To an observer on the earth, therefore, viewing the sun at the time of the vernal equinox in successive years, the path of that body will *seem* to be toward 270°, right ascension. Again, the declination of the sun will likewise suffer a change in journeying the quadrant from A to B, a change which can be resolved into two factors, namely; first, an uprighting of the axis to the extent of 23½° in one direction; and, second, a tilting of the axis to the same amount in a new direction at right angles to the former. The net effect upon the *apparent* movement of the sun in declination, then, will be, *not the sum* of 23½° plus 23½° but the *hypothenuse* of the right angled triangle two of whose sides are equal to 23½° traced on the celestial sphere. Applying the appropriate rule, then, we have:

$$\sqrt{2 \times (23\tfrac{1}{2})^2} = 33.23$$

That is to say, the drift of the sun will SEEM to anyone *not in possession of the key* to be, not merely to right ascension 270°, but also to declination +33°.23. On a similar line of reasoning, it can easily be seen that the *vertices of* *preferential motion* of the stars should *appear* to be respectively in r. a. 90°, dec. 11.75°, and r. a. 270°, dec. -11.75°, showing that the so-called star streams are clearly nothing other than an optical illusion. Now compare these results with those derived by others by the laborious and conventional methods of empirical observation and analysis. I quote from Doctor W. W. Campbell's *Stellar Motions* (p. 147):

> Below are solutions for the apex of the sun's motion and for the vertices of the two star streams, by Kapteyn, Eddington, and Dyson; and for the positions of the solar apex and of the vertices of Schwarzschild's ellipsoid of preferential motion, by Schwarzschild, Beljawsky and Rudolph.

| | Apex | | Vertex | |
|---|---|---|---|---|
| | R. A. | Dec. | R. A. | Dec. |
| Kapteyn—Bradley stars | | | 91° | +13° |
| Eddington—Groombridge stars | 266° | +31° | 95 | + 3 |
| Schwarzschild—Groombridge stars | 266 | +33 | 93 | + 6 |
| Dyson—Stars of large proper motion | 281 | +42 | 88 | +24 |
| Beljawsky—Porters stars | 281 | +36 | 86 | +24 |
| Eddington—Zodiacal stars | | | 109 | + 6 |
| Rudolph—Bradley stars | 268 | +26 | 96 | + 7 |
| Rudolph—Bradley stars | | | 87 | +11 |
| Means | 272 | +34 | 93 | +12 |

A *logarithmic spiral* is defined as one that intersects all radiants at the same angle. This is precisely the ensemble arrangement we should expect of the planets in their orbits at successive instants of time, if, as I have been arguing, the planets are truly balancing themselves as a composite unit on the pivot of their lowest center of gravity. Strangely enough, astronomers have lately shown that spiral nebulæ (which for this purpose possess an advantage in having continuous arms to guide the eye, whereas a system like ours has only points) conform to this very shape! I would ask the reader to pay especial attention to this peculiarity, as it will be adverted to later in an even more important connection.

It may be objected by some of my readers that the axis of the sun, Jupiter, and Uranus are not at all in alignment with the earth's axis. The objection, on the face of it, is sound and legitimate, and deserves a categorical answer. Let it be premised, however, that the only planet enough like our earth in constitution to serve for a criterion, to-wit, Mars, points its axis so nearly like the earth's that Doctor Lowell, late director of the Flagstaff Observatory, in a bulletin issued shortly before his death, asserted that its inclination is *identically* that of the earth's. Why this remarkable coincidence? Shall it be waved aside as immaterial? Moreover, Saturn's axial inclination is given by Flammarion as 25° 42′ as against 23° 27′ for the earth. Close enough surely to constitute a *prima-facie* case! As far as the definite exceptions of the sun and Jupiter are concerned, I might put astronomers in general on the defensive by saying, truthfully, that Newtonian theory doesn't account for the direction of even a single one of these axes, let alone for these three amazing coincidences. But I will not thus evade the question.

When you look at the earth, you see its crust; when you look at the sun or Jupiter, you see only their atmospheres, or, at least, fluid envelopes. You cannot, therefore, predicate with the same positiveness with respect to the *hidden* axial inclinations of these as you can with regard to the *plainly visible* ones of Mars and the earth. In the case of the earth, its interior (at least relatively to the interiors of Jupiter and the sun) is solidified, and incapable of free movement, so that her ballasting adjustments are confined, perhaps exclusively, to the surface, where they can be duly interpreted; whereas the sun, and, in all likelihood, Jupiter, also, are molten throughout, so that their ballasting process may go on inside, secretly, leaving their mobile surfaces freely open to centrifugal balancing. The force of this explanation is strengthened by the established fact that both these huge bodies exhibit the singular phenomenon of "*equatorial acceleration*"; that is, the rotation of neither is uniform from pole to pole, but is faster at the equator than in the latitudes.

You may ask me why the solar system rotates on its axis from west to east instead of just the reverse. I do not know, any more than I know why the water in the basin sometimes turns toward the right, and again toward the left. All I can say is, it had to move one way or the other, *and then stick to that way.* The die could have been cast by the first comet that crossed the nebular field, just as the mere touch of the tip of your finger on the water in the basin will determine the direction of its rotation.

Again, you may wish to know why the ecliptic and the plane of the Antarctic Circle of the Gravisphere correspond, instead of the ecliptic being tangent to the Sphere. I appeal again to the surface of the basin of water for the explanation. You have observed, have you not, how the surface *dishes in,* forming, as it were, a saucer? This, obviously, is an effect of the centrifugal force generated by the principle of balance, and I assume that the same principle holds good in the case under discussion. At any rate, the ecliptic does not exactly correspond with the plane of the circle, though the *''invariable plane''* of the system perhaps does.

It would seem to follow that, inasmuch as the rotations in our system are accelerating, the time periods are intrinsically shortening. On the other hand, however, the faster bodies are whirled the farther out they fly. For reasons which seem to me convincing, I believe that the earth is *receding* from the sun by infinitesimal degrees, and also that the year is shortening as well. This, however, is needlessly speculative and I will pursue the idea no further. The thing of importance is, that *we have ferreted out the hidden force that whirls the planets around and counteracts the centripetal attraction.*

# IV

# THE TIDES

THE ebb and flow of the tides is altogether too conspicuous and important a phenomenon of nature to have escaped the notice and observation of the ancients, and long before Newton's day it was shrewdly suspected that some sort of causal relationship subsists between the movements of the moon on the one hand and the behavior of the tides on the other. By the time Newton arrived on the scene, this suspicion had developed into a general scientific conviction, although no explanation had yet been suggested. The circumstantial evidence on which this conviction is founded may be briefly summed up as follows:

Besides her apparent diurnal revolution around the earth from east to west, the moon has a real motion around our planet in the opposite direction, from west to east, a circuit which she completes (from new moon to new moon) in about 29½ days. On account of this latter motion, the moon's time of rising is delayed from one day to another by an average period of 51 minutes. Now, the strange part of it is that high tide arrives at any given port by this same interval of 51 minutes later each successive day, and the natural inference arises that the moon is somehow the cause, and the tide the effect. But the coincidence extends even farther, for it has been demonstrated that the *height* of the tide varies rhythmically with the moon's changes of phase, being highest at the syzygies and lowest at quadrature. Furthermore, the tide is higher by about 20 per cent when the moon is at perigee than when at apogee.

Newton himself was so completely persuaded by this evidence of the moon's being the mother of the tides that it never occurred to him, nor indeed does it seem to have occurred to anyone but the present writer, to cast about for any other solution. That a new solution is imperatively demanded, however, is rendered certain by the candid confessions of the Newtonians themselves, who, after two centuries of ceaseless striving to fit their theory to nature, have finally agreed among themselves that the two are utterly irreconcilable. Professional astronomers, of course, all know this without needing to be told; but in order to satisfy the lay reader that such is really the case let me quote these additional passages from Young and Darwin (See also p. 10 *ante*):

> The establishment of a port is the mean interval between the time of high water at that port and the next preceding passage of the moon across that meridian. At New York, for instance, this establishment is 8h. 13m. although the actual interval varies about 22 minutes on each side of the mean at different times of the month. (*Genl. Astr.,* p. 403)

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> It is interesting to reflect that our tides today depend even more on what occurred yesterday or the day before in the Southern Pacific and Indian oceans than on the direct action of the moon today * * * * *the problem is one of insoluble mystery.* (Darwin's *The Tides,* p. 188).

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> In fact, the evanescence of the diurnal inequality is not much closer to the truth than the large inequality predicted by the equilibrium theory; and *both theories must be abandoned* as satisfactory explanations of the true condition of affairs. (*Ibid.,* p. 180.)

It is but one of many glaring inconsistencies of modern astronomical science that, in spite of these and an unlimited number of other such damning admissions of the objective falsity of Newton's tidal theory, our scientists nevertheless continue to teach it in the schools as one of the great scientific gospels. All the so-called modern cosmogonies—the Planetesimal hypothesis of Chamberlin and Moulton, Arrhenius' theory of Light-Pressure, See's hypothesis of a Resisting Medium, and the rest,—are based in whole or in part on this *admittedly* false doctrine. Indeed, in the very book in which he gave utterance to the paragraphs just quoted, Darwin goes on and elaborates his grotesque theory of *Tidal Evolution,* of which, in concluding, he himself speaks in these slighting words (*The Tides,* p. 284):

> There is nothing to tell us whether this theory affords the true explanation of the birth of the moon, and I say that it is only a wild speculation incapable of verification.

To cap the climax of absurdity, the article *Tides* in the new *Britannica* was contributed by this same Darwin, and it is given up almost wholly to the exploitation of this "wild speculation incapable of verification" to the exclusion of virtually all other pertinent matter! What a travesty is this on science! Here we have, in chronological order: first, Newton's theory; second, universal admission of its unsoundness; third, a complicated elaboration of the theory by one who had already condemned it; fourth, condemnation of the elaboration by its own author; and fifth, the memorializing of the author and his "wild speculation" in the chief publication of the world!

## *NEWTON'S THEORY OF THE TIDES*

Inasmuch as the tides *rise* it was natural enough for Newton to surmise, in the first instance, that they are caused by gravitation *lifting* the waters away from the earth proper; and inasmuch, also, as there exists a coincidence between the moon's schedule and the schedule of the tides, it was not less natural for him to infer, at least provisionally, that the moon, rather than the sun, is the primary tidal force. Accordingly, he conceived the moon as drawing the oceans immediately under her away from the earth's solid part or kernel, and the kernel in turn away from the nether oceans, thus causing the *double* tide that observation reveals to exist.

When he came to compute the relative attractions of the sun and moon, however, he found that, after making due allowance for their respective masses and distances, the attraction of the former upon our earth is 180 times stronger than the lunar attraction. Such a result was, of course, incompatible with his primary hypothesis that the moon is the greater tidal force (a hypothesis which, alas! he took to be axiomatic), so he cast about in his mind for a way to reverse the order of their potency, and to twist things to fit.

Continuing his argument, he reasoned that the waters that actually compose the tidal hillock are to be differentiated from the level mass of the ocean in this, that they are the part displaced, having to be drawn in from the surrounding regions. Such being the case, the attraction of the moon which drew them in could not have been, at first, vertically exerted upon them, but obliquely, and the same reasoning applied equally to the sun's attraction. It consequently followed, mathematically, that the tidal forces vary, not as the inverse squares (the law of gravitation) of the distances of the sun and the moon, but as their inverse cubes. Computing anew on this basis Newton made out the moon to be about four times stronger, tidally, than the sun, instead of 180 times feebler.

Observation, from Newton's day to this, has failed to reveal any signs of a separate double *solar* tide, which theory indicates should exist. According to modern computations, the ratio of the two tidal forces is, roughly, two to one instead of four to one; hence the academical argument for the visibility of such a separate solar tide looms stronger to-day than it appeared in Newton's age. He sought to explain the physical absence of this tide by postulating a *merger* of the solar with the lunar tide, at one time augmenting and at another offsetting it, according to the relative angular positions of the two bodies with respect to the earth.

Now, although it is quite true that there is a startling coincidence between the measure of the daily advance of the moon eastwardly in her orbit and the interval between the arrival of successive high tides at any given port—51 minutes in both cases—there is a no less startling *discrepancy* as to the meridianal places of the moon and high tide at any given moment. According to the main hypothesis, high tide should occur *immediately under* the moon; for instance, when the moon is on the meridian of New York, high tide should then be filling that city's harbor. *Instead,* we find that when this latter event occurs the moon has preceded it by about eight hours, and is already some thirty degrees below New York's western horizon! Why this great *hiatus between cause and effect?* Newton claims it is due to the "dragging" of the tides, arising from the presence of interposing land masses, friction on the ocean beds, and the inertia of the water itself.

The assumption that the moon draws the oceans away from the earth's solid part clearly implies a superiority in the degree of the intensity of her attraction upon the oceans, as contrasted with her pull on the kernel, and a relative holding back of the latter. Newton knew as certainly, although not so accurately as we, that the density of the earth's solid part is several times greater than that of water and that, by the strict law of mass, the kernel, notwithstanding its slightly greater distance from the moon, should be attracted much more powerfully than the oceans in front of it. He knew, also, that the resultant effect of such action could only be to *shallow* the seas on the earth's moonward side instead of deepening (raising) them. This conclusion, however, did not suit Newton's preconceptions in the least, for it meant retracting his previous reasoning, restoring the original, to him obnoxious, ratio of 180 to 1 in the sun's favor, and in short, relinquishing altogether his cherished theory of the lunar causation of tides. Unequal to this sacrifice, he sought a way out of the dilemma by tampering again with his own law of gravitation. As one lie leads to another, so one basic misinterpretation of nature's laws leads to an endless chain of absurdities. He had already dared to distort the second clause of the law to read that tidal forces vary, not as the inverse squares but as the inverse cubes of the distances, hence he now felt driven, in the interest of consistency, to go on and alter the first clause to match its changed companion. Accordingly, he made that to read, that gravitational attraction, when operating as a tidal force, disregards differentiations of density! In support of this new absurdity, he introduced what is known as the vacuum-tube experiment (to be discussed later), from which he drew the fallacious inference that, inasmuch as all objects, regardless of density, fall in vacuo with the same rapidity, the law of equilibrium does not apply to them or, by analogy, to cosmic bodies in general.

Newton's next step was to invent some method, favorable to his theory, for computing the tidal heights. Making use of his rule of inverse cubes, he ascertained the tidal force of the moon to be 1-2,871,400 of the earth's gravity and that of the sun, 1-12,868,200. (Young gives 1-8,640,000 and 1-19,600,000 respectively) The question with him was: How are these quantities to be translated into terms of tidal height so as to obtain *plausible* results?

It was well-known to the generation before Newton that the figure of the earth is not that of a sphere, but of an oblate spheroid, and her equatorial ring seems always to have been assumed, as a plain matter of course, to be the *running* effect of the centrifugal force of her axial rotation. This view was blindly adopted by Newton himself, and is the one universally acquiesced in to-day by all recognized scientists. Some skeptical lay readers may infer that the ring, to some extent at least, may be the cumulative effect of the long past, but let me assure him solemnly that this is *not* the orthodox interpretation. In the time of Newton the thickness of this ring at the equator was supposed to be 85,472 Paris feet (a Paris foot being about 1-15 longer than the American standard), but the modern estimate is only 13-½ miles (71,280 feet).

By a combined process of pendulum experimenting and computation, Newton arrived at the conclusion that the centrifugal force of the earth's rotation at the equator serves to lighten any given body at that place by 1-289 of the weight it would have were the globe at rest; that is to say, the centrifugal force there is equal to 1-289 of gravity. Continuing, he reasoned that, inasmuch as this force, being equal to 1-289 of gravity, sufficies to elevate her equatorial regions by 85,472 feet, the attraction of the sun, which is 1-12,868,220 the strength of gravity, should be able to elevate those regions by 289 times 85,472 feet, or 24,701,408 feet divided by 12,868,200, or very nearly 2 feet. But let me quote his own words (Book III, Prop. 36, *Principia*):

> Cor. Since the centrifugal force of the parts of the earth, arising from the earth's diurnal motion, which is to the force of gravity as 1 to 289, raises the waters under the equator to a height exceeding that under the poles by 85,472 Paris feet, as above, in prop. 19, the force of the sun, which we have now shewed to be to the force of gravity as 1 to 12,868,200, and therefore is to that centrifugal force as 289 to 12,868,200, or as 1 to 44,527, will be able to raise the waters in the places directly under and directly opposed to the sun to a height exceeding that in the places which are 90 degrees removed from the sun only by one Paris foot and 11-1/30 inches, for this measure is to the measure of 85,472 feet as 1 to 44,517.

At this stage Newton appears to have rested his case, but not so his successors, who have had the desperate courage to pursue his fatal logic further, even to the bitter extreme of swallowing the inescapable *reductio ad absurdum* that neither the moon or the sun is the dynamical cause of the tides, but that the *centrifugal force of the earth's axial rotation is!* Nor, granting the premises laid down by their leader, can one find any fault with their logic, as such. Suppose, say they, that the earth did *not* rotate on its axis at all, then there would be no centrifugal force and, by the same token, there could be no equatorial ring and, incidentally, *no tide.* Test the matter for yourself: Substitute in the Corollary *zero* wherever the quantity 85,472 feet appears and you will find that, no matter how stupendous the tidal forces of the sun and moon might nominally figure out, Newton's method of computing would, *did the planet not rotate,* inevitably reduce them all to nothing. Here is what no less a personage than the late lamented Sir Robert Stawell Ball, the most famous English-speaking astronomer of our day, says on this subject (*Story of the Heavens,* p. 539):

> The tides are, however, doing work of one kind or another. A tide in a river estuary will sometimes scour away a bank and carry its materials elsewhere. We have here work done and energy consumed, just as much as if the same task had been accomplished by engineers directing the powerful arms and navies. We know that work cannot be done without the consumption of energy in some of its forms; *whence, then, comes the energy which supplies the power of the tides? At a first glance, the answer to this question seems a very obvious one. Have we not said that the tides are caused by the moon? And must not the energy, therefore, be derived from the moon? This seems plain enough, but, unfortunately it is not true.* It is one of those cases, by no means infrequent in Dynamics, where the truth is widely different from that which seems to be the case. An illustration, perhaps, will make the matter clearer. When a rifle is fired, it is the finger of the rifleman that pulls the trigger; but are we, then, to say that the energy by which the bullet has been driven off has been supplied by the rifleman? Certainly not; the energy is, of course, due to the gunpowder, and all the rifleman did was to provide the means by which the energy stored up in the powder could be liberated. To a certain extent we may compare this with the tidal problem; the tides raised by the moon are the originating cause whereby a certain store of energy is drawn upon and applied to do such work as the tides are competent to perform. *This store of energy,* strange to say, *does not lie in the moon; it is in the earth itself.* Indeed it is extremely remarkable that *the moon actually gains energy from the tides by itself absorbing some of the store which exists in the earth.* This is not put forward as an obvious result, it depends upon a refined dynamical theorem.
>
> We must clearly understand the nature of this mighty store of energy from which the tides draw their power and on which the moon is permitted to make large and incessant drafts. Let us see in what sense the earth is said to possess a store of energy. We know that the earth rotates on its axis once every day. *It is this rotation which is the source of the energy.* Let us compare the rotation of the earth with the rotation of the fly-wheel belonging to a steam engine. The rotation of the fly-wheel is really a reservoir, into which the engine pours energy at each stroke of the piston. The various machines in the mill, worked by the engine, merely draw upon the store of the energy accumulated in the fly-wheel. *The earth may be likened to a gigantic fly-wheel detached from the engine though still connected with the machines in the mill.* From its stupendous dimensions and from its rapid velocity, that great fly-wheel possesses an enormous store of energy which must be expended before the fly-wheel

comes to rest. *Hence it is that, though the tides are caused by the moon, yet the energy they require is obtained by simply appropriating some of the vast supply available from the rotation of the earth.*

It is quite true that many astronomers, without, however, making any pretense of logical demonstration, hypothesize the existence of a *statical* tide, that is to say, a tide *on a non-rotating body.* Standing by itself, this is an eminently sensible idea; but, *taken in connection with Newton's process of computing it, it is a wholly unwarranted assumption.* Besides, does not Young say, "In fact the statical theory becomes utterly unsatisfactory in regard to what actually takes place"?

Boiled down to its dregs, then, this is Newton's Tidal Theory:

1. The moon is the primary cause of the tides, and the sun the secondary.

2. The actual, or dynamical, cause of the tides is, nevertheless, neither sun nor moon, but the centrifugal force of the earth's axial rotation. In fact, the moon even feeds upon the energy of this rotation.

3. The elevation known as the earth's equatorial protuberance is the running effect of that centrifugal force.

4. The tides are likewise the running effect of this same centrifugal force.

5. This centrifugal force exists of itself without any pre-existing cause.

6. There is no way by which this force is replenished. The earth is on the order of "a fly-wheel detached from the engine," only that, in the earth's case, there never was any engine so far as we know.

7. To sustain in place the equatorial ring, this centrifugal force continuously expends out of its stored energy 1-289 of the power of gravity, and, to produce the lunar tides, 289-2,811,400 of gravity.

8. Notwithstanding this lack of an engine and these dissipations of energy, the centrifugal force remains intact forever.

9. The explanation of this mystery is that the centrifugal force is *persistent* in character, this word having been suggested by Spencer as an improvement on Newton's word inertial. The discovery of this synonym is esteemed one of the great triumphs of cosmic science.

10. The moon's tidal force is employed in dragging the tides from where the major premiss of the theory says they are generated and ought to appear, to exactly those places where the same theory says they are out of place and ought not to be.

11. The theory is based on the law of gravitation by converting the clause that reads "varies directly as the product of their masses" into "varies regardless of their densities," and the clause "inversely as the squares of their distances," into "inversely as the cubes of their distances."

12. It denies the law and principle of equilibrium in its application to cosmic bodies.

13. Weighed by the physical facts "it is nearly as much wrong as possible."

14. "It is one of the most well-attested facts of human knowledge."

### NEWTON'S THEORY CRITICISED

Since the death of Newton in 1727, the accumulation of scientific data has proceeded with Brobdignagian strides, and this is true of astronomy no less than of the other physical sciences. Linnaeus, the father of modern botany, was only twenty when Newton died; Dalton, the originator of atomic chemistry, was not born until nearly forty years later, 1766; Cuvier, the founder of systematic zoölogy, in 1769; Charles Darwin, in 1809. These celebrated names imply that there is more for man to do than merely to acquire stores of isolated items of information; they connote *classification and generalization of these data into systems* that not only broaden our concepts, but supply keys to much that remains unknown.

Now, if the fundamental truths were the first to come into our knowledge, the building up of a science would be a comparatively simple matter. But they by no means do so. Even so, little harm would come of it, were it not for the proneness of all of us to think and act mechanically, along conventional lines, and to look with disfavor and often with contempt on the ''crank'' who presumes to set his opinions up against those of the reactionary majority. Since Newton's day, numerous such *fundamental* truths in astronomy have come to light that our scientists have been treating as minor and tacking here and there onto the most convenient niches in the superstructure, instead of courageously razing, as they should, the ramshackle structure to the bed rock and rebuilding solidly with free hand and fresh initative.

Who among us, I ask, gifted with ordinary intelligence, a heart of perseverence, sufficient leisure, an overpowering love for and interest in the subject, and means of access to the great stores of modern data, should not be capable of constructing *de novo* a better system of cosmology than Newton or any other man or genius could be expected to do in a day when such basic indispensable truths as the following were unknown and unsuspected?

1. The age of the earth. Newton conceived it as especially created for man only 6000 years ago, and that, in another paltry millennium or so, it is doomed to perish in flame and ashes. This notion of the earth's transiency narrowed his outlook on the greater universe most pathetically, insomuch that, in all his deliberations, he overlooked altogether the relations of the solar system to the stars, and treated it as a universe unto itself. (2) He did not know of the sun's motion, or that the stars move in regular courses. (3) He took no account of the greatest dynamical factor in nature, namely, the composite of the stellar attractions. (4) He never heard of

the existence of nebulæ, for these were not discovered by Sir Wm. Herschel until two score years after Newton's death, hence the characteristic forms of these wonderful objects carried no suggestion to him. (5) He knew of the existence of only six great planets. Had he known of the asteroids, he might have thought twice before predicating divine agency to set these, like the great planets, in what he conceived to be miraculous and studied motion. (6) He knew of the secular acceleration of the moon, but he did not foresee that mathematics alone would never solve it. (7) The problem of the origin of the sun's heat troubled him not, for to him it was transient as the earth. (8) He had no ideas whatever about the genesis of new stars, or about their variability. (9) The use of steam as a source of mechanical power was unknown, and, of course, so was the mechanical theory of heat as well. (10) Spectrum analysis had not yet demonstrated that the sun and stars are essentially of the same chemical composition as our base earth. (11) Finally, Newton lacked the advantage we possess of factual knowledge that his tidal theory is all wrong. Had he had this knowledge he might have taken a second thought and, retracing his steps, hit upon the true solution. After severally weighing this formidable array of his handicaps, ask yourself whether the presumption should be in favor of, or against, Newton's theory of tides or, for that matter, any of his theories, and what should be our duty in the premises?

It is curious that our Newtonian friends, who lay such great store upon the value of the *concordance* of moon and tide in the single particular that each has the same habit of arriving at any given port 51 minutes later each succeeding day, pedal most softly on the *dissonance* between the meridianal places where these phenomena respectively appear at the same instant of time. According to Newton's main hypothesis, the tidal crest should exist at all times nowhere but *exactly beneath* the moon. Were this, indeed, the case, the causal relationship between moon and tide would be all but conclusively demonstrated. But the uncompromising fact is that the tide which the moon is alleged to raise up *under* her, *never by any chance appears anywhere near there,* but invariably hides below her horizon some eight hours in her wake!

Having, let us say, been freshly taught by our Newtonian savants as to how the moon causes the tides, and, furthermore, that gravitation acts *instantly* over very great distances, our first impulse is to glance at the nearest expanse of ocean to note the evidential phenomena. But instead of beholding the expected hillock, we really see a hollow! Dumfounded, we conjure up apologies for the solecism, as, that the water here is too shallow, or the expanse too restricted, and the like. Accordingly, we decide to test out the hypothesis under the most favorable conditions possible, and for this purpose select the central meridian of the Pacific, on the equator, where the ocean is at its deepest, when the full moon is in the zenith, and where there can be no suggestion of continental resistances to hinder the tidal process. But even here, *here, under ideal conditions,* we behold, not a rise, but a more pronounced depression than ever! and we recall Darwin's words once more, "It would seem, then, as if the tidal action of the moon was actually to *repel* the water instead of attracting it; *and we are driven to ask whether this result can possibly be consistent with the theory of universal gravitation!*

Now the tide must come into being *somewhere* and *somewhen,* and it must *exist* before it can be "dragged". If it be not lifted into being under the ideal conditions mentioned above, when or where else can it be generated with greater certainty and facility, or more promptly? Again, if it arise not there until many hours after the moon has passed, how can she drag thence *against resistence* what she could not and did not lift, *unresisted, on the spot?* While, amazedly, we are pondering these contradictions, our Newtonian cicerone pulls us by the sleeve and learnedly says, "The tide never forms where it is created, save only in lofty scientific contemplation; but look away off into the mid-Atlantic. *There* is the tide," he explains, "that the moon gave birth to yesterday while here over the Pacific; but, in the meantime, she has dragged it thence overnight around the curve of the globe. Eight hours hence, when the moon, now in her zenith, has descended 30 degrees below our western horizon and is soaring over India'', he goes on, ''the crest of the tide will arrive here in the midst of the Pacific, and we shall speak of it as this day's tide.'' Ask him at what meridian yesterday's tide dies out and to-day's begins; whether the tide of the Atlantic dissipates itself by contact with the eastern shores of the American continent, or is dragged around Cape Horn into the eastern Pacific; whether, if it be thus dissipated, the Pacific tide is not also dissipated upon the eastern shores of Asia, India and Africa and never enters the Atlantic at all—and he will answer you somewhat as Darwin does, ''It is interesting to reflect that our tides to-day depend even more on what occurred yesterday or the day before in the Southern Pacific and Indian oceans than on the direct action of the moon to-day—*the problem is one of insoluble mystery.''*

Again, according to Newton, the terrestrial waters located on the moonward side flow toward that body, while the waters on the nether side tend toward the lunar antapex. Now, the crests of *all* the tides at *all* times are invariably *located below the moon's horizon,* consequently they belong to the nether hemisphere and, by premiss, *should seek the antapex.* But observation shows otherwise, for the main tide keeps coursing up the earth's side incessantly, seemingly determined to rise into the moonlit hemisphere,—a feat, however, which it never achieves. In short, whether we regard the tide as part of the moonlit hemisphere or as part of the other, its behavior is equally contradictory of the Newtonian hypothesis.

Only a little insight is required to reveal that Newton pictures the moon as doing and *undoing* its alleged work at one and the same time—a house divided against itself. Could you look down from the moon you would see no sign of the tide, for the crest of it is perennially hidden from her sight and even some thirty degrees *around the bend* of her horizon. Now let me ask you to translate yourself in spirit to that point in the moon's orbit diametrically opposite her, and thence to look down upon that side of the earth. According to Newton's primary hypothesis, where ought you to find high water? Why, at the point vertically under you, in the very center of the disc. But where do you *really* find it? I answer you, *along the marginal rim* of the disc. Strange contradiction! Here we are told that the moon's function is to gather the waters to the places under and opposite her, and in the next breath we are solemnly informed that by virtue of that same power she foils herself and *drags those waters away from herself to the places most distant* from those central spots, and what is more, *perversely keeps them away!* According to theory, the tidal crest should not roll toward the rim as it does, but toward the center or antapex, which in fact it really FLEES. Inconstant moon! Bringing to bear her full lifting power directly upon the upturned sea, with no resistance to counteract her, all she can do is to *indent the surface!* With everything against her—continental resistances, the curvature of the earth, *even her own contrary pull*—she drags the tide after her without a slip or a break! Every process of dragging against resistance implies retardation in geometrical ratio: how comes it, then, that after, through this cause, having fallen behind the moon 120 degrees, the tidal crest thereafter eternally holds its full integrity and speed, instead of softly diffusing into a neutral sheet?

We are informed that the moon causes a double tide, that is to say, one tide on the side of the earth that faces her, and a secondary tide on the earth's face hidden from her. The first of these is understood to be the tidal crest which follows the moon by the interval of about eight hours (120 degrees). For brevity, let us call this the "follow" tide. Assuming that the secondary tide is normally diametrically opposite this, or 180 degrees behind, the former should in fact be just 60 degrees in front of the moon's position; hence we may, for convenience, call this secondary tide the "leader." Now, if there is any merit in the conceit that the moon makes a business of dragging tides around, why does she not lasso the leader tide, where it rolls less than a quadrant ahead, and drag it back to her, and so fulfill the major hypothesis? This argument, in itself so reasonable, is made stronger by the circumstance that, whereas the follow tide, in its effort to reach the moon, is obstructed by the frictional resistances conjured up by Newton, the same sort of resistances rising up in the path of the leader tide ought to abet the moon's effort to catch up, and drive that tide back into her corralling arms. My point, in brief, is this, that if it be indeed true that the moon creates the tide by uplifting the ocean waters in the manner conceived by Newton, there is no valid physical reason or argument why the effect should not run even with the cause, instead of counter to it, as it so plainly does.

It will scarcely be disputed that the tidal elevation is necessarily subject to a continuous levelling or wasting process, tending toward the general smoothing over of the ocean surface, and that, in order that the tide may persist, it must be continuously recuperated. Such restorations must, perforce, occur on the spot, not thousands of miles away. Between the Cape Verdes and the Hawaii Islands stretch about 120 degrees of longitude, so that when the moon soars over the latter, the tide washes the shores of the former. By what dark magic does the moon thus ventriloquize her tidal mandate from where she stands at work, back around the bow of the earth, to the eastern Atlantic? A straight line drawn from the moon at any time to the tidal crest would pierce the earth hundreds of miles below the surface, and it is plainly to be seen that the attraction of the moon, acting directly along such a line, will attack the tide through the earth from underneath, and should tend to level, not to augment its height. The Newtonians, however, in their vaunted wisdom, picture the attraction of the satellite as turning the curve of the earth, as round a pulley, and laying a prehensile hand upon the tide and hauling it forward by main force.

Newton's idea of how the tides are formed, namely, by the drawing away of the nearer waters from the kernel, and the latter in turn from the rearward waters, contemplates, as its vital feature, an actual physical displacement of all three in the line of the moon's radius vector. Let us see just what such possible displacements would mathematically amount to and whether or not they measure up to the requirements.

According to the principle of gravitation, any object, for example an apple, falling earthward, attracts as much at it is attracted, for, viewed from either end, the tractive tension is identically the same. This does not signify, however, that in coming together earth and apple will meet half way, but rather that they will traverse distances *inversely proportional to the square roots of their masses.* A while back, we saw that the moon has been computed to fall 1-19 of an inch per second. Since, however, she is only 1-81 of the earth's size, the latter should theoretically fall moonward only 1-171 of an inch in the same brief period. This computation, be it noted, is based on the original law of the inverse squares, which Newton repudiates in favor of his improvised rule of inverse cubes. Adopting *his* rule, we shall have to reduce our already small fraction by multiplying the denominator by 60 (the moon's distance being 60 times the earth's radius), whence we derive the quantity 1-10, 260 of an inch as the measure of the lunar tidal deflection of the earth per second. But this quantity, again, must be halved, for the reason that there are hypothetically two tides, fore and aft, each of which must be allowed an equal share of the provided space, yielding us only 1-20,520 of an inch for each. Summing it all up, Newton's conception contemplates that the moon by drawing the oceans on the near side away from the earth's kernel the infinitesimal fraction of 1-20,520 of an inch per second, at once creates and provides room for a tide 8½ feet high, or more than 2,000,000 times its own magnitude! Doubtless some will retort that the tide is the work of a day and not merely of a second. Very well, grant even this for the sake of argument and say the effect is cumulative for a full day and thereafter remains uniform. In a day there are 86,400 seconds: multiply this number into 1-20,520 of an inch and you get, even with this improvident concession, the paltry space of only 4½ inches, or 22 times less than what the case requires. For the tide to reach the high altitude of 8½ feet that Newton gave it, the tidal force would have to accumulate for nearly a month! To my mind, however, it is quite as preposterous to suppose such cumulativeness to take place for the period of a day as for a year, and I hold that the tidal force and the tidal effect are mutually commensurate from one second to another, and that it is for each individual second to tell its own tale. To get an idea of the woful inadequacy of this ratio of 1 to 2,000,000, then, the reader may mentally compare a tub of water to Niagara's overflow in the space of a full minute! To just this extent does Newton's hypothesis fall short of the actual dynamical requirements.

In making his computations of the tidal heights, even on his own theory, Newton committed two serious oversights. The first of these was in erroneously treating the *entire* thickness of the equatorial ring as being centrifugalized instead of only one-half of it. The other half of the ring is, of course, rightfully in place, being a part of the original ideal spherical shape. For it should be plain to any person of intelligence that subtracting a unit from one of two equal quantities and adding that unit to the other quantity will make a difference of two units, and not merely of one. Accepting as correct the estimate of the earth's polar diameter at 7,899 miles, and of the equatorial at 7,926 miles, given out by the National Geographical Society, the disparity between the two is 27 miles. Were the earth molded into a perfect sphere, the terrestrial diameter would be uniformly 7912.5 miles. To deform the earth, then, into its present shape required the centrifugalizing to the equatorial belt of 13½ miles of thickness from the polar axis. But we must not overlook the circumstance that this excess matter is evenly distributed all around the equator, consequently the thickness of the ring at any given point exactly on the equator is 13½ miles and the centrifugalized part of it only 6¾ miles, or only 35,640 feet as compared with the 85,472 feet adopted by Newton. Had Newton done what rightly he should have done, and divided his quantity by *two,* he would have reduced his tidal heights for sun and moon to about 5½ inches and 4 feet 4 inches, respectively, and, on the like supposition, Flammarion's estimates would fall to 4.7 and 9.9 inches.

Newton's second blunder lay in assuming that the *entire* equatorial ring, the whole 13.5 miles, is composed exclusively of water, though he could not help but know that not more than one-sixth of it is so constituted. A strict regard for accuracy should have prompted him to allow for the probability that the land masses and the rocky bed of the ocean, which together make up the other five-sixths, are upheld not by centrifugal force at all but by their solid supports. As a matter of fact, however, he made no such allowance, nor do his successors to this day, nor has anyone in their behalf attempted to offer any apology for the omission. The reason is plain enough, for to do so would be to render their estimates too ridiculously trivial for consideration, namely, Newton's, 1 inch and 9 inches, and Flammarion's, .8 and 1.8 inches respectively. To me, however, the most amazing thing about the whole business is the cool nonchalence with which the whole tribe of Newtonians help themselves to this fund of "centrifugal force" without bothering themselves in the least as to whence it came, or how it is recuperated! They resemble the prodigal wife who could not comprehend why her credit with the bank had run out, because of the fact that she still had a plenty of blank checks on hand. It is a wonder to me that, with all their unrivaled genius for invention, astronomers have not yet been able to invent a "persistent" bank account, and so rendered themselves independent of the donations they are continually soliciting from a generous public.

Although astronomers, as a class, openly profess to subscribe to every tit and tittle of Newton's tidal theory down to the final deductions that non-rotating bodies cannot bear tides and that the axial rotation of the earth supplies the power for the terrestrial tides, yet such is the saving power of common sense over abstract theory that these same astronomers flirt with the heretical notion of the possibility of the existence of a statical *tide on non-*

*rotating bodies.* However, this new notion *may* be rendered compatible by employing another method than that of Newton to compute the tidal heights, a method, too, that on the face of it is decidedly more logical in every way, for it not only permits of the postulation of a statical tide, but also shifts the task of producing the tides in general from the centrifugal force of the earth to the moon's attraction, where Newton initially meant to place the credit.

According to Sir John Murray, the average depth of the oceans is 12,480 feet, or about 149,760 inches. Let us, if you please, consider this water as a prize being wrestled for by the earth, on the one hand, seeking to maintain it in a quiescent state of equilibrium, and the moon, on the other, striving to capture it from her. As we have already seen, Newton estimated the moon's tidal force as only 1-2,871,400 of gravity. To get a concrete basis of comparison between these two forces, then, in terms of ocean depth, all we need do is to divide 149,760 inches by 2,871,470; giving for a result approximately one-twentieth of an inch, or about the thickness of shoe leather. Of course, this result is ridiculously out of proportion to the phenomena to be explained, but let the blame fall on the theory, where it belongs, and not on my method of computing it, which is logically sound. The average daily rainfall for the whole earth is almost exactly one-tenth of an inch. Assuming the average daily evaporation from the surface of the sea to be the same, there looms out the astounding *reductio ad absurdum* that, on Newton's own showing, the sun's evaporating effect is just twice as great as the moon's tidal force! Besides, the sun raises *his* burden clear to the clouds.

Most of my readers, I daresay, imagine with Sir Robert Ball, the earth to be a body so enormous, and the energy of its axial rotation so immeasurably great, that the theoretical drains scientists impose upon it are relatively too trivial to cut any material figure. Suppose we investigate this matter in the spirit of the Missourian and let us first take up the factor of the dynamical sustentation of the equatorial ring. In his presentation of the Newtonian point of view, Sir John Herschel (*Outlines of Astronomy,* Art. 224) says:

> Now, it is highly satisfactory to find that the general elliptical figure thus *practically* proved to exist, is precisely what *ought theoretically* to result from the rotation of the earth on its axis. For let us suppose the earth a sphere, at rest, of uniform materials throughout, and externally covered with an ocean of equal depth in every part. Under such circumstances it would obviously be in a state of *equilibrium*; and the water on its surface would have no tendency to run one way or the other. Suppose, now, a quantity of its materials were taken from the polar regions, and piled up all around the equator, so as to produce that difference of the polar and equatorial diameter of 26 miles which we know to exist. It is not less evident that a mountain ridge or equatorial continent, only, would be thus formed, down which the water would run into the excavated part at the poles. However solid matter might rest where it was placed, the liquid part, at least, would not remain there, any more than if it were thrown on the side of a hill. The consequence, therefore, would be the formation of two great polar seas, hemmed in all around by equatorial land. Now, this is by no means the case in nature. The ocean occupies indifferently all latitudes, with no more partiality to the polar than to the equatorial. Since, then, as we see, the water occupies an elevation above the center no less than 13 miles at the equator than at the poles and yet manifests no tendency to leave the former and run toward the latter, it is evident that it must be *retained* in that situation by some adequate power. No such *power,* however, would exist in the case we have supposed, which is therefore not conformable to nature. In other words, the spherical form is not the *figure of equilibrium,* and *therefore* the earth is either not at rest, or is so internally constituted as to attract the water to its equatorial regions, and retain it there. For the latter supposition there is no *prima facie* probability, nor any analogy to lead us to such an idea. The former is in accordance with all the phenomena of the apparent diurnal motion of the heavens; and, therefore, if it will furnish us with the *power* in question, we can have no hesitation in adopting it as the true one.
>
> Now, everybody knows that when a weight is whirled round, it acquires thereby a tendency to recede from the centre of its motion; which is called the centrifugal force. A stone whirled round in a sling is a common illustration; but a better for our present purpose will be a pail of water, suspended by a cord and made to *spin round,* while the cord hangs perpendicularly. The surface of the water, instead of remaining horizontal, will become concave. The centrifugal force generates a tendency in all the water to leave the axis, and press towards the circumference; it is

therefore, urged against the pail, and forced up its sides, till the excess of height, and consequent increase of pressure downwards, just counterbalance its centrifugal force, and a *state of equilibrium is attained.* The experiment is a very easy and instructive one, and is admirably calculated to show how the *form of equilibrium* accommodates itself to varying circumstances. If, for example, we allow the rotation to cease by degrees, as it becomes slower we shall see the concavity of the water regularly diminish; the elevated outward portion will descend, and the depressed centre rise, while all the time a perfectly *smooth* surface is maintained, till the rotation is exhausted, when the water resumes its horizontal state. (The italics are all his.)

You cannot have forgotten our former experiment of whirling the ball at the end of the string, and how I tried to make clear the fundamental distinction between the principle of that experiment, embracing as it does a "flinging motion" outward from the center, and the case of the earth and moon, in which such a flinging motion is conspicuous by its absence. I furthermore pointed out the unsavory fact that astronomers affect to believe that the two phenomena are exactly analogous.

That instance has a parallel. The experiment I now refer to is the one purporting to illustrate and explain to advanced pupils the cause of the earth's equatorial protuberance. An elastic hoop is provided and so adjusted on a vertical axis that by means of a crank it can be rotated around its axis at a high velocity. As the crank is turned faster and faster, the hoop is seen to elongate horizontally and its vertical axis to shorten correspondingly, making an ellipse out of what was before a true circle. Here the experiment is invariably brought to an abrupt close. The lesson it is intended to teach is that the earth's oblateness is the *physical effect of her axial rotation.*

Now it is most earnestly to be hoped that no undergraduate can be discovered so preternaturally dense as to require to be shown this silly experiment in order to teach him no more than the *a priori* knowledge that such ENFORCED rotation must produce just such effects. What he wants to know, what you want to know, what the world wants to know, and what these blind teachers of the blind cannot answer is, What *keeps* the earth turning on her axis? The experiment of the hoop demonstrates admirably that as long as you are content to *turn the crank* the hoop will not only dutifully rotate, but that it will also remain distended. But it also most emphatically demonstrates that the hoop will infallibly *cease* doing either of these things *the moment you suspend your exertions.* That eminent Newtonian, Sir Robert Ball, veraciously confesses, as we have seen, (p. 90) that the earth *has parted company with its engine,* but the machinery, he adds, is still attached. In spite of the cranking power having, as Ball imagines, taken an indefinite vacation, the earth does not seem to mind, but goes on expanding herself, or rather keeping herself expanded, from age to age and whirling upward her tides without exhibiting any sign of slackening or weariness. Here, again, observe the want of flinging power discretely sidestepped and its place supplied by the iteration of that euphonious but vacant phrase of Spencer's, "persistence of force." What a saving of fuel there would be if all the fly-wheels in our innumerable factories could be brought to respect this Spencerian philosophy! You might hunt the lunatic asylums through without being able to discover a poor victim so hopelessly bereft of reason as to imagine that a fly-wheel *detached from its engine* will continue to run the machinery without coming to rest. Even the perpetual motion unfortunates recognize the *need of a power source.*

Suppose that, while the hoop is rotating at its highest speed and consequently expanded to the limit, you were sufficiently deft to insert in it a horizontal brace, you could then shut off the driving force without impairing the deformation attained; otherwise the natural elasticity of the steel will cause the hoop to spring back into its original shape. Again, you might accomplish this distension of the hoop in other ways, as, by setting a heavy weight upon its rim while it stood in an upright position, or by stretching it with your hands, or by compressing it in a vise. And yet again, if the hoop were very large, or relatively very thin, or composed of some softer material, as lead, *its own weight* would tend to flatten it. in short, there are numerous ways whereby the hoop may be altered in shape, and by analogy, there may well exist *more than one way to account for the oblateness of the earth.*

To ascertain just how much energy is required to distend our hoop to any given degree of elongation, all that is necesssary is to hang it on the hook of a balance scale, lend your weight to the hoop until the desired elongation is obtained, and then read the scale. To effect this elongation *by cranking* requires power—a steady flow of power or energy—exactly equal to the elastic strength of the steel, as previously ascertained on the scale, or, what is the same thing, *to the sustaining against gravity of a weight of that same magnitude.* It not only required a great expenditure of energy on the part of the earth's momentum to whirl the excess water to the equator in the first instance, but it takes a steady supply of power to *keep it there.* An illustration which may make the matter clearer is that of a horse just able, by putting forth all his strength, to sustain a weight stationary in mid air at the end of a pulley: though the weight does not rise, yet the horse labors hard just to *preserve the status.*

Again. Suppose that the hoop instead of being made of spring-steel were made of some material that would not give while rotating, but continue to retain its original circular shape, what then? Which operation, think you, will require the greater expenditure of power; to rotate the rigid hoop at a given number of revolutions per minute, or, the elastic one? The deformation of the latter cannot, of course, be effected without the absorption of power; shall we then conclude that to rotate it at the same rate of speed as the other will require just this much *additional* power? Assuredly not! "But," you may say, "then the act of deformation does *not* absorb energy as at first supposed? How can we explain this apparent paradox?" The answer is plain enough. That part of the centrifugal force which in one case manifests itself in elongating the elastic hoop, that is to say, causes visible distortion, transforms itself into heat in the case of the rigid one by forcing its molecules violently against each other, from within outward. Let this pressure pass a certain mark and we have the phenomenon of an explosion, as, indeed, often occurs in the case of fly-wheels.

These reflections bring out still another radical distinction between my views and those of Newton, namely, that whereas he claims that having once been given its rotation, the earth will continue to rotate forever by sheer inertia, because it cannot stop itself, I hold that the earth, even if it were absolutely rigid and possessed a mathematically spherical shape, would automatically bring itself to axial rest by converting and yielding up its centrifugal force into kinetic energy, or heat, and radiating the same out into space. There simply *must* be some driving power behind the earth's rotation. What is it? Is it natural or supernatural, mechanical or miraculous, real or imaginary, physical or verbal, inertial or creative? *Calling* a fly-wheel persistent will not enable us to dispense with the engine, nor will it serve any better for the earth's case.

The reader will perhaps remember that, in a former chapter, I adopted, as a convenient and sufficiently near standard for the purpose, the sustaining of a ton-weight stationary against gravity as equivalent to one horse-power of energy. Doubtless this is an overestimate of the power, but, if so, it is an error on the safe side and will nevertheless satisfactorily serve our present purpose.

Let us, then, first inquire how much centrifugal force is consumed by the work of bolstering up the hill of water in the equatorial regions and preventing it from flowing down to the lower level of the arctics; for the dead weight of this mass answers to the elastic tension of the steel hoop in our former experiment, and since the water is not dammed, power alone will avail to hold it steadily above its natural level. According to the authorities, the weight of the oceans is in round numbers 1,400 quadrillions of tons, of which, let us say, only *half* is thus energially supported. It follows then, from the premises, that either some 700-quadrillion-horse-power engine which science has as yet failed to locate is spinning our globe round and round, or that the storage battery of the axial momentum of the earth is *losing* 700 quadrillions of horse-power right along. If the former be the case, what is that power? If the latter, how long can the earth's momentum hold out, and why doesn't the rotation slow down, even a little bit?

Again, accepting Sir Robert Ball as spokesman for his fellow astronomers to the effect that the energy that produces the tides emanates not from the sun or moon, but out of the earth's store of centrifugal momentum, let us see what this, also, amounts to. Flammarion gives the sum of the lunar and solar tides as (approximately) 30 inches at the equator. Taking their average height for the whole world as 15 inches, and limiting this again to only half the ocean surface (75,000,000 miles), gives a weight of water thus alleged to be perpetually whirled upward by the earth of, in round numbers, 80 trillions of tons. As this action is going on *all the time,* it means that, on this second count, the centrifugal force is wasting away at the steady gait of 80 trillions of horse-power.

The complacent reader may think to himself that, huge as these drains upon the rotational energy of the earth seem to be, they must, nevertheless, be negligible in comparison with their source, else *our Newtonian friends would not dare to draw upon that source so extravagantly as they do.* Now, it is easily possible to ascertain the magnitude of this *supply* in terms of horse-power within reasonable limits of accuracy. Assuming that one-half of the earth's mass is contained within an inner core 6,000 miles in diameter, and that the average velocity of the whole mass is the same as the velocity of any point on the equator of that core, the distance covered in a single second would be 1160 feet. This is manifestly an overestimate, seeing that, in the higher latitudes, the velocity is necessarily much less, and, for convenience, we may arbitrarily reduce this quantity to 1116 feet per second, which, though still too high, happens to be one-third of the orbital velocity of the moon and therefore simplifies the present calculation by furnishing us with a convenient standard for comparison.

Now, in Chapter II, if you remember, I computed the energy value of the momentum of the moon, traveling as she does at the rate of 3350 feet per second, to be 2,112 trillions of horse-power days (8.8 x 240 trillions). Multiplying this quantity, then, by 81 because of the earth's greater mass, but dividing the product by 9 (the square of 3, since the energy varies with the square of the velocity) because of her slower (axial) speed, we obtain the sum of 20,000 trillions as the total number of horse-power days "stored" in the earth's axial momentum at this given instant. Compare this solitary energy asset now, if you please, with our liabilities as previously appraised, and you will be startled to find that were it to be applied solely to the sustentation of the equatorial ring it would exhaust itself in the brief space of *less than a single hour,* or if applied wholly to the raising of the tides, in just 250 days! What is the answer? How comes it that our asset remains obviously intact in spite of these stupendous drains? Can Sir Robert be right in likening the earth to a fly-wheel *detached from its engines?* Did you ever see a "fly-wheel detached from its engine, but still connected with the machinery" fail to betray signs of slowing up almost immediately, and shortly come to a dead stop? Furthermore, what sort of an engine was it to which the terrestrial fly-wheel we call the earth was once attached, and how did it become *de*tached, and where is it now?

Tide or no tide, equatorial ring or none, it is not true that a great ball like ours, even were it the only one in existence, could, once started, continue to rotate forever "because there would be nothing to stop it." There *is* such a something—*gravity.* It has been estimated that the earth would have to rotate 17 times as fast as it does before a loose rock, say, on its surface "would lose all its weight and fly off to become a self-sustaining satellite." Now, it seems quite plain that if the earth as a whole is to keep on turning itself round and round forever, every particle of it must be capable of doing its own carrying and not depend for levitation or propulsion on its neighbors, who have equal need of like help themselves. According to Newtonians, the rotation of the earth lightens any given object at the equator by only 1-289 of its weight, so that a mountain weighing, say, 289,000 tons may be provisionally construed to be self-sustaining by virtue of its "persistent" momentum to the extent of 1000 of its tons, but as to the remaining 288,000 tons it must be regarded as a *burden imposed upon some carrying agency underneath it.* The bed of rock on which the mountain reposes is, in turn, along with its load, a still weightier burden on the next stratum beneath, and so on down to the center of the earth. But the earth's center is only a mathematical point! Nowhere do we come across any sign of a motive power. There are only two ways of dealing with this mystery. One is by appealing to the miraculous, *alias* "celestial mechanics," as the Newtonians do; the other by placing the finger on the *substantial cause.* That cause, I hope to convince the reader is none other than the tides themselves.

# VI

## THE LAW OF EQUILIBRIUM

THAT objects near the earth's surface seek their lowest center of gravity, or, what is the same thing, their equilibrium, was known long before Newton's time quite as well as it is in ours. Indeed, it may truly be said to have been *better* understood then than now, for the reason that Newton, in his quest for the solution of the mystery of the tides, introduced a perversion of the law that has ever since obsessed the scientific mind and incidentally worked untold injury to the cause of astronomical science. This *pseudo* doctrine of which I speak teaches that bodies lose the power of self-balancing when falling in vacuo, and is founded upon what is commonly known as the vacuum-tube experiment, which is thus succinctly described in Ganot's Physics (Art. 77):

> Since a body falls to the ground in consequence of the earth's attraction on each of its molecules, it follows that, everything else being the same, all bodies, great and small, light and heavy, ought to fall with equal rapidity, and a lump of sand without cohesion should, during its fall, retain its original form as perfectly as if it were compact stone. The fact that a stone falls more rapidly than a feather is due solely to the unequal resistance opposed by the air to the descent of these bodies; in a vacuum all bodies fall with equal rapidity. To demonstrate this by experiment a glass tube about two yards long may be taken, having one of its ends completely closed, and a brass cock fixed to the other. After having introduced bodies of different weights and densities (pieces of lead, paper, feather, etc.) into the tube, the air is withdrawn from it by an air pump, and the cock closed. If the tube be now suddenly reversed, all the bodies will fall equally quickly. On introducing a little air and again inverting the tube, the lighter bodies become slightly retarded, and this retardation increases with the quantity of air introduced.

Now, it is a sound and cardinal rule of experimental science that the experimenter shall not allow his personal predilections to color the result. Unfortunately, Newton and, worse still, all who have since been led to repeat this particular experiment have started out with no other possibility in mind than that the moon is the major cause of the tides; and it is therefore not at all surprising that all of them alike have fallen blind victims to the same blunder. Nor, when we recall the countless instances in the past of the tenacity of traditional error, should it be any more surprising that Newton's tidal hypothesis has survived in human opinion the positive disproof of the same by Nature herself.

The worst fault I have to find with modern astronomy is its impotency to rid itself of the ancient propensity of trying to interpret the phenomena of the firmament by systematically differentiating between *terrestrial* natural law and *celestial* natural law. The one great truth I seek to inculcate is that *natural law is everywhere identically the same, from center to circumference of the physical universe,* be it finite or infinite. Metaphysics and physics are independent worlds. You cannot rationally postulate uncaused rectilinear physical motions or assert that persistence and inertia are equivalent terms and still claim to be a scientist in the ideal sense. Here in this question as to the universality of the law of equilibrium we have another such case in point. It would seem that Newtonians look upon the principle of equilibrium as a sort of incubus upon matter, a mistake of Nature's as it were, and that they feel that they are performing a signal service to her by cogitating this base mundane impediment out of existence in the "nobler" universe above us. Terrestrial objects, say they, are bound by the law of equilibrium; celestial bodies, on the contrary, are of a higher order and are absolved from such servile obedience. With them "celestial mechanics" is not terrestrial mechanics applied to stellar objects, but rather an elaborate transmogrification of it. Where Newton did not hesitate to invoke divine agency to explain such physical wonders of the heavens as he himself could not fathom, his followers, more materialistically given, have aimed to supply the place of the Deity by the banality of alleging such wonders to be "natural", without taking over the burden of showing *why* and *how* they are natural. They convince themselves that the sun and the stars are dashing through space, and then they go on and say it is "natural" for *all* celestial bodies thus to dash through space, and that the phenomenon "demands explanation only as mere existence does." They behold one member of a binary star circling about its fellow, so they declare "the central one whirls the other round and round," and that such behavior is natural, *up in the sky.* They see the earth rotating on its axis, and this again they sagely inform us is natural, also, else why, forsooth, should it be so rotating? Furthermore, seeing the equatorial ring, they say that such momenta as inhabit planetary bodies are different "by nature" from terrestrial momenta in this, that they are "persistent," and can go on doing work forever without any fresh feeding of the motive power. All these so-called laws (!) they affect to believe true of *celestial* mechanics; and, in line with this policy, they teach that the vulgar law of equilibrium is altogether too corporeal to consort with these supernal archetypes.

Far from being a clog upon matter, whether here or in the sky, whether in this paper weight or in the terrestrial globe of which it is a part, *the principle of equilibrium is an inestimable endowment indispensable to the preservation and regulation of the universe in all its activities and through all its broad extent.* Here on earth, is not equilibrium the ruling factor that makes for *order* as against *confusion,* for *system* as opposed to *chaos?* Why should it be preferentially assumed, then, that, in the greater cosmos, the principle should prove itself otherwise? As well might one advocate the abolition of rudders as being an impediment to ships, which otherwise would be free to move indiscriminately. The one great truth, rising mountain high above all others in the realm of physical science, is, that natural law is irrevocably unchangeable, and that, for all its inflexible rigidity, the universe it controls is at once fraught with kaleidoscopic changes of infinite range, yet withal perennially maintained *in order*. So must it ever continue, as ever it has continued.

If astronomy is to qualify to take a rightful place among the so-called natural sciences, its devotees must outgrow the ancient habit of viewing the firmament through metaphysical glasses. The doctrine of conservation of moment of momentum is quite as much a philosophical abstraction as the Ptolemaic one that planets revolve in exact circles; the dogma of the persistency of planetary motions, as miraculistic as the parable of the loaves and fishes; the self-projection of celestial bodies, as frankly contra-natural as Joshua's halting of the sun. Thanks to Copernicus, Kepler, Galileo, and Newton, astronomy has, indeed, escaped out of the umbra of medievalism, but it is still whelmed in the penumbra that sees only a fraction of the full truth. Astronomers of to-day, unlike the ancient sages, no longer worship the inanimate sun, moon and planets as so many gods and goddesses; nor did Pope Pius on the last apparition of Halley's comet, in 1910, follow the superstitious example of his predecessor, Pope Calixtus III, who, on the occasion of its appearance in 1456, ordered the bells in all the churches to be rung and prayers to be said by everyone for the purpose of exorcising the comet, which he and all his generation believed to be an evil spirit. In this connection it may be illuminating to modern readers to scan the following passages from the pen of Sir David Brewster (*Memoirs of Newton,* v. II, pp. 81 and 313), as giving an insight into the extent of Newton's own teleological views, and particularly as showing that he was not oblivious to the unbridged gaps in his cosmological theories:

> To make such a system with all its motions, required a cause which understood and compared together the quantities of matter in the several bodies of sun and planets, and the gravitating powers resulting from thence; the several distances of the primary planets from the sun and of the secondary ones from Saturn, Jupiter and the earth, and the velocities with which those planets could revolve about those quantities of matter in those central bodies; and to *compare and adjust* all these things together in so

great variety of bodies, argues that cause to be not blind and fortuitous, but very well *skilled in mechanics and geometry.*

In concluding this brief notice of the progress of physical astronomy since the time of Newton in a few of its leading features, we are naturally led to ponder on the great truth of the stability and permanence of the solar system as demonstrated by the discoveries of Lagrange and Laplace. In the present day, when worlds and systems of worlds, when life physical and life intellectual are supposed to be the result of general law, it is interesting to study those conditions of the planetary system which are necessary to its stability, and to consider whether they appear to be the result of necessity or design. It follows, from the discoveries of Laplace, that there are three conditions essential to the stability and permanence of the solar system, namely, the motion of all the planets in the same direction,—their motion in orbits slightly elliptical, or nearly circular,—and the commensurability of their periods of revolution. *That these conditions are not necessary is very obvious. Any one of them may be supposed different from what it is, while the rest remained the same. The planets, like the comets, might have been launched in different directions, and moved in planes of various and great inclinations to the ecliptic. They might have been propelled with such varieties of tangential force as to have moved in orbits of great ellipticity; and no reason, even of the most hypothetical nature, can be assigned why their annual periods might not have been incommensurable.* The arrangements, therefore, upon which the stability of the system depends, must have been the result of design, the contrivance of that omniscience that foresaw all that was future, and that infinite skill which knew how to provide for the permanence of His work.

Another thing which doubtless has had a considerable retarding influence upon the trend of astronomical thought, and which still makes its presence felt, is the use of the same words—celestial, heavens, heavenly, and the like—to designate both things spiritual and things firmamental. The reader may judge for himself the strength of this influence by a mental analysis of what such a phrase, for example, as "celestial mechanics" means to him. I would respectfully ask whether it does not connote for him a sort of *transcendental* mechanics, a mechanics in some sort liberated from the rigid inflexibility of our mundane natural laws and one, too, necessitating the postulation of laws and principles *peculiar to cosmic* as contradistinguished from terrestrial objects?

If it does, and if this be the significance the term possesses in the consciousness of scientists in general, the sooner it is revised the better. With these reflections in mind, then, let us see if we cannot make shift to resurrect the law of equilibrium out of the tomb Newton prepared for it, and utilize it to good purpose in the working out of that greatest of all physical problems, the structure of the universe.

## NEWTON'S VACUUM-TUBE EXPERIMENT

In the first place, let it be remembered that this experiment was designed and undertaken with but one object in view, namely, to prove up Newton's rashly-conceived hypothesis regarding the cause of the tides. Had subsequent investigations of the tidal phenomena borne out the hypothesis, the fact would have constituted an all but conclusive confirmation of the basic lesson drawn from the experiment. Far from this being the case, however, we are informed by such lofty authorities as Darwin, Kelvin and Young—Newtonians all par excellence—that the tidal hypothesis is "utterly unsatisfactory in regard to what actually takes place," and that "it is nearly as much wrong as possible." If there is any merit in the logic of facts, then, it follows that the hypothesis, having been weighed in the balance of Nature and found wanting, every link in the chain of deduction is forcibly brought under suspicion. The staple link in this chain is the vacuum-tube experiment; why, then, should *its* soundness be taken for granted? In view of the disastrous outcome, is not the probability precisely the reverse?

In the next place let me ask, What is the physical or causal relationship, if any, subsisting between the surrounding medium and the equilibristic tendency of any object therein contained? Is there, perhaps, some secret virtue in the atmosphere that, passing into the object, imparts to it the power or imposes upon it the obligation to lower its center of gravity? And, conversely, does the withdrawal of the air from the receiver deprive it, *pro tanto*, of that power or absolve it from that obligation?

If this is what Newtonians really mean to imply—and it is difficult to construe their attitude otherwise—they throw themselves open to a gross inconsistency, namely; in denying to the earth, in their tidal theory, the power of equilibrium, for the earth is blessed with a stupendous atmosphere. Moreover, supposing it true that the medium *does* possess such virtue, then unsymmetrical objects resting on the floor of the vacuum should be as exempt from the law as at any height within that chamber; whereas the undeniable fact is that such bodies upright themselves just as certainly as they do in air or water. It is as clear as day that in this case *the medium functions only by moderating the velocity of the fall*, thereby affording the investigator *time* and *facility* for studious observation.

Obviously, then, the principle of equilibrium exists altogether independently of the atmosphere. Its real essence—how can any one doubt it?—lies in gravitation, nothing else; and, like the latter, or rather because both are of the same essence, it can no more abandon any particle of matter, or be filched from it, than can gravitation itself. In olden days it used to be argued that when a balloon rose in air, it was because gravity had ceased to act upon it. One of the best answers to that fallacy was that the balloon, even when in the act of rising, continuously observes the law of equilibrium, keeping its heavier part underneath. To-day we have the same old dispute resurrected, but at the other end of the chain. *Now* it is the principle of equilibrium that is at issue. By means of an opposite sort of device, man has invented a way of causing objects to fall with even greater velocity than they do in air, and to fall so rapidly, indeed, that their subtle efforts at self-balancing successfully elude the keenest eye. Thus is the presence of the principle of equilibrium obscured now, as was the presence of gravity formerly in the phenomenon of the balloon. It is a poor rule, they say, that doesn't work both ways; Why not then apply the converse of the old reasoning? Why not say, inasmuch as the action of gravity on the balloon, in spite of its act of rising "against gravity," was legitimately inferrable from the circumstance of the balloon's preserving its lowest center, so the action of the law of equilibrium, in the case of the object in the tube, though masked from our perception behind its high velocity, is reciprocally *inferrable from the fact of the fall?*

How, do you suppose, was the existence of a center of gravity in objects originally discovered? By casually noting the fall of apples from trees? Certainly not! The unmistakable way was to choose a suitable object, immerse it in a liquid, and then watch its behavior. To this process two things were essential; the first being that the object examined be left perfctly free to turn upon itself; the second, *that it be kept steady enough to allow the eye opportunity for critical inspection.* No one will question the commonsensibleness of this method, and, indeed, our modern physicists even as late as this know of no better way.

Now, when Newton came to prove up his tidal theory, he found the knowledge of the law of equilibrium there before him, and he did not find it to his liking; for, as I have previously stated, it did not accord with his major premiss that the moon is the chief tidal force. Most of us have the faults of our virtues, and Newton was no exception. Always fertile in expedients, he was sometimes as inventive in the pursuit of error as he was at other times in the cause of truth. Precisely retracing the course by which the law had originally been brought to light, he one by one *systematically restored all the obstacles* that aforetime had blocked the road to its unearthing, and, by this unworthy subterfuge, *undid discovery* and relegated this inestimable diadem of knowledge back again into the limbo of the Unknown. His tube having to be of glass, to ensure transparency, and glass being by nature very fragile, it was manifestly impracticable to provide one of even moderate length, so it was actually made *but five feet long.* Moreover, the tube needing to be hermetically sealed as a necessary condition to the pumping out of the enclosed air, it became automatically *impossible to introduce instruments for precise measurements,* supposing such exactness to have been desired. Finally came the *removal of the resistance* by conscientiously exhausting the air. Having carefully gone through all these maneuvers and satisfied himself, for the last time, that Nature was now effectually gagged, he called to her: "Prove to me now in the wink of an eye that these objects, as they fall through this tube, obey your boasted law of equilibrium. If you fail, I will brand you for all time to come as the most inconstant of your sex." Newton made no allowance, *nor wished to make any*, for the brevity of the time, the extreme shortness of the fall, the persistence of retinal impressions, the notorious uncertainty of the human eye in general, his own mental bias—all he aimed at was to confirm his already fixed opinion and to clinch his ill-fated tidal hypothesis. But Nature, after generations of misrepresentation passed, finds voice at last through Kelvin, Darwin, Young and the rest and proclaims that the hypothesis is "as false as can be." Alas, she has been silent too long, and not even her mouthpieces heed her testimony!

Ask any modern physicist whether a shell fired from a mortar observes the law of lowest center, and he will unhesitatingly answer, yes. He cannot see even the path of the shell, much less the gyrations of the missile upon itself, but for all that he is none the less positive. Why? Because he intuitively reasons to the truth beyond this negative evidence. He will sensibly argue, "I cannot perceive grass grow, but I know it does grow. I cannot detect the motion of the stars, and for ages mankind believed them absolutely fixed, but science has now demonstrated that they *do* move, and at astounding velocities. With my naked eye I cannot see animalcules, but the microscope reveals to me their existence". All this he will say, and more; yet, in the end, he will reiterate with unabashed finality, "I cannot descry any sign on the part of the object falling in the vacuum to seek its lowest center of gravity, *ergo,* I deny that it does so."

If there is anything that science can take just pride in, it is in those inventions which have extended human knowledge into domains *beyond our direct sense perceptions.* The telescope revealed to Galileo the rings of Saturn, the four moons of Jupiter, and the phases of Venus; and improvements of the instrument have brought to light countless other wonders. No doubt the bigoted Libri, Galileo's bitterest critic, had he had the power, would have been glad to reverse the telescope for all time, as a means of guarding mankind from the perils of unbelief. In effect, that is just about what Newton did. He found humanity possessed of the knowledge that bodies seek their lowest centers of gravity, a knowledge which had previously been arrived at by painstakingly bringing within the purview of human perception what before had been hidden from sight; and, for mere expediency's sake, he deliberately suppressed that knowledge by snuffing out the torch by whose light it had been revealed. In short, he "reversed the telescope," and for this all the scientific world has never ceased to hold him in reverence! Forced to choose between Newton's tidal theory and Nature's solemn contradiction, our modern astronomers uphold the first against the last, so great is the prestige of Newton to-day, who, during his long life, was ridiculed and condemned. For what use is it that man has invented the telescope, the microscope, the thermometer, the barometer, the bolometer, the spectroscope, the photographic plate, etc., if their valuable evidence is thus to be arbitrarily set aside to suit the exigencies of crazy hypothesis?

Of course, there is the possibility that many scientists are already convinced, not necessarily from any arguments I have here advanced, but as a result of their own private reflections. However, they have none of them, so far, seen fit to speak out; possibly because of a wholesome and well-founded dread of the hierarchical lash. Your Newtonian professor may, indeed, say with Darwin that the tidal theory is as false as can be, but he must, under peril of dismissal, subserviently couple the heresy with the retraction that he believes in it notwithstanding, and that he will continue faithfully to teach it to his classes as one of the gospels of science. You may, however, test his sincerity, if you will, after some such manner as the following:

Provide yourself with a pair of false dice so heavily loaded as to turn up sixes at every throw, and let the casting of pairs of sixes constitute the winner. Exhibit these to any Newtonian of your acquaintance, not concealing from him their fraudulent character. Then, taking a perfectly true pair of dice from your pocket, hand them to him and say: "Here, friend, is a pair of honest dice for you. Let us throw for the dinners. Do you use your dice, casting them in the ordinary manner in the open air, but let me shake my false ones within a vacuum tube—pairs of sixes to win." If he is consistent at heart—scruples of conscience aside—he should take you up on the instant. But *will* he? Think the matter over.

Theoretically, it would be possible to extend the original vacuum-tube experiment to the other extreme; that is, we may suppose the tube lengthened to, say, ten miles. In that case the act of falling would consume just about one minute—surely not too long to grant Nature a fair chance to absolve herself from the stigma of vacillation that Newtonians have thrust upon her. Incidentally, we may imagine the tube capacious enough to allow for the introduction of suitable micrometrical devices to record the equilibristic gyrations of the object, not only at the instant of alighting, but also in the course of descent. Of course, all this is *practically* impossible, and if Nature must await her vindication until such a thing becomes practicable, she is likely to remain in disgrace until all human interest in the issue has died out. Fortunately for her and us, however, she has thought to set out documentary evidence of her consistency on the scroll of the sky. I refer to the moon. Why, do you suppose, does our satellite continually turn the same face toward us, unless it is because her visible hemisphere is the heavier; and why does she exhibit her librations, if not because of the conflicting attractions of the sun and of the Prime Resultant?

Now conceding—solely for the sake of argument, however,—that the moon is really falling earthward at the rate of 1/19 inch per second, then the earth, being 81 times heavier, must be falling moonward only 1/171 inch in the same brief instant. This is tantamount to saying that the earth, if falling moonward at all, is falling only one inch in about 3 minutes! Suppose that by some device you could, by manipulating a switch, control gravitationally the velocity of a loaded die in the tube so that it would fall as slowly as this, thereby giving you ample opportunity to observe it closely, and it abundant time to adjust itself,—Do you conscientiously doubt that the die would turn its loaded side underneath, just the same as it would if sinking slowly in a glass of water?

Here I fancy the reader exclaiming, "But you are mistaken in asserting that Newton predicated his conclusion upon the behavior of the individual object; he, on the contrary, inferred it, and correctly, from the fact that objects of very diverse densities, such as a feather, cork, bullet and the like, fall with exactly equal velocity."

My first reply to this is, that when you use the word "exactly" in this connection, you display a confidence in your seeing skill that I am far from feeling in my own. For my part, I think that there is as much, and more, uncertainty in correctly deciding the race between two particles, such as a long feather and a tiny spherical bullet, traveling but a yard or two of height at great velocity, as there is in deciding for example, close plays at second base in a professional game of baseball. Umpires, at least, know how little dependence is to be placed on the visual judgment of the average "fan." It is truly amazing, the concordance of opinion between the umpire and the crowd, when his decision favors the home team, and equally astounding how little that same umpire's judgment is respected, when he decides a close play in favor of the visitors. In the case of the particles, everybody, from Newton down, has been all along betting on the race as a tie, with no takers, and it is not to be wondered at that the verdict is enthusiastically unanimous.

But even admitting the cogent argument of "preponderant opinion," it is quite as much of a *non sequitur* to hold, that because objects fall in vacuo with identical velocities, they individually repudiate the law of equilibrium, as it is to assert, that a pellet of lead and a pellet of chalk of exactly the same size and shape, likewise falling together in a vacuum tube, will strike the bottom with equal force because they are traveling with equal velocities. Two racers may easily cover the specified distance in unison, but that doesn't preclude each from balancing himself separately, or regulating the length of his own stride.

But even waiving all that has gone before and taking the Newtonian experiment *at its face value,* I still take exception to it, not merely because it does not reproduce the cosmic conditions, which may be excusable, but *because it does not sensibly parallel them.* The Newtonian deductions, in the light of the experiment, may be thus itemized:

1. *Objects in vacuo, irrespective of their varying densities, fall with precisely equal velocities.*

2. *Cosmic bodies are only objects of a larger growth, are constructively falling, and are falling through the void of space; therefore they, also, and all their component molecules fall with equal velocities.*

3. *All objects, great and small, thus falling in vacuo maintain throughout their descent both their initial inclinations and their original shapes.*

Let us try this conception out by analyzing a simple hypothetical case:

Imagine, if you please, that some power should arrest the moon in her orbital flight, hold her steady for a moment, and then gently drop her. According to Newtonians, she would fall in one attitude straight downward to the earth, where she would arrive in something less than a week's time. Suppose, again, that the same power that arrested the moon should at the same moment cause to spring into existence, round a point just 3,000 miles this side her center, a globe of water of exactly the same mass, and that both these moons were allowed to drop simultaneously. What would be the result? Were we to apply the reasoning of Newton, as based on his aforementioned experiment, we should have to argue somewhat after this fashion. Here are two large "objects" falling together through a vacuum. They must therefore fall with precisely the same velocity, preserve throughout their respective initial inclinations and shapes, retain their separate individualities, and, finally, strike the earth one after the other. Or, as Ganot puts it, "Everything else being the same, all bodies, great and small, light and heavy, ought to fall with equal rapidity, and a lump of sand without cohesion should, during its fall, retain its original form as perfectly as if it were compact stone."

Such, I say, is the solution tendered us by Newton and his disciples. Let me now submit my own: Although it is quite true that each of the two moons is only 1/81 as massive as our planet, they are, on the other hand, eighty times nearer each other than their common center of gravity is to the earth. Let it be remembered, however, that attraction varies *directly* as the mass, but inversely as the *square* of the separating distance, whence it plainly follows that the net attraction between the moons is eighty times greater than that between their joint mass and the earth. This condition would result in a singular thing, namely: The aqueous ball, being solicited moonward far more powerfully than earthward, it would, for a time, actually rise away from the earth until it should meet the true moon on her way down. The impact of such a meeting would, of course, *per se,* deform both colliding bodies; but this would not be the sole result. The integral power of attraction of the coalescing mass would immediately come into play—a constructive, as the collision was a destructive force—and this would automatically remould the whole into a globular form, in which new state the merged moons, continuing their descent, would strike the planet as one.

*Which of these analyses does the reader prefer,* the first based on the *denial* of the law of equilibrium, or the second, *founded on the law itself?*

To sum up, then, it plainly appears: First, that the unanimous admission of our modern scientists is, that Newton's theory of tides is completely contradicted by the phenomena; second, that in spite of its known falsity, they nevertheless universally teach and follow it as true; third, that in spite of its known falsity, all recent cosmogonies are unconditionally grounded upon it, and hence must stand or fall with it; fourth, that the confirmed practice of our astronomers is to seek the solution of cosmic problems, not by uncompromising adherence to strict natural laws, but by industriously searching for loopholes of escape from it, not by the legitimate unfolding of the established principles of terrestrial mechanics, but by the invention of a sort of super-mechanics that may serve to admit the introduction of teleological explanations under the guise of being natural and normal; and, lastly, that the Law of Equilibrium to which Newton sought to give quietus, and which his followers have all along believed dead, still survives to rule and order the universe of stars.

## KEPLER'S LAWS

Newton demonstrated to the satisfaction of expert mathematicians (who, by the way, alone can follow and comprehend his treatise), that Kepler's laws and the law of gravitation are in harmony. As the proponent of the proposition that the law of equilibrium is just as deeply rooted in this great law of gravitation as are Kepler's laws, it would seem to devolve upon me to establish, mathematically, the *essential identity of all three.* I shall therefore make the attempt:

The reader will remember that I recognize three sorts of gravitational units, namely; (1) a simple body, like the moon; (2) a compound body, like the binary earth-moon system, and (3) a complex body, consisting of a multitude of planets and satellites, all balancing themselves around their common center of gravity. Moreover, I define a gravitational unit as a single body, or a congeries of cosmic bodies, seeking its lowest center of gravity. The proposition I am now going to try to prove is, that our solar system is a family of such bodies so intimately associated with each other, by virtue of their mutual attractions, and so distantly removed from the stars in general, as to behave as a consolidated mass in this: that, while in the act of falling in the direction of the resultant of the stellar attractions, they seek their *common systemal center of gravity* and revolve around each other according to the

### LAW OF THE LEVER OR BALANCE ARM

It is a fact already well recognized by astronomers, that the moon does not revolve around the center of the earth, but around the center of gravity of their joint mass, and that a similar principle holds good of the planets with respect to the sun. So far, then, the principle of the balance arm has been scientifically accepted. But this knowledge does not dispose of the riddle as to why these bodies rotate at all; it does not explain the impulsion that lay, or lies, behind those tangential or centrifugal motions, nor does it point out what keeps them going. My conception is, that the orbital movements of the circulating bodies is due to their act of falling at the command of the Prime Resultant, and that instead of falling down in straight lines, *as they would do were their mutual attractions dissolved,* they fall with a spiral twist that carries them perpetually round and round their common center of gravity. In short, the solar system, I hold, is an immense clock driven by its own descending weight.

In order to get as clear a notion as possible of the torsional effects of the stellar attractive forces, let us recall the little laboratory experiment we tried before with the yardstick and the strings. But suppose now, that instead of using the ring, you twist the strings round and round one another at the point where the ring was, and then do you and I pull as before. In such case, the rod will be seen to make *numerous* revolutions, as many, indeed, as there were windings to the strings.

Now, it is impossible for us, here on earth, to reproduce in all respects an imitation of the gyrations of the solar system in free space. We are endowed, however, with human intelligence, which ought to enable us to reason these things out for ourselves. Imagine, then, two stars away off by themselves in space, yet near enough to each other to constitute them a binary system. Now visualize to yourself, if you please, the rays of gravitational attraction proceeding from all the stars in the universe, and from all sides, to each one of our pair of stars in turn, and you cannot but see that the two systems of rays thus produced cross each other much as did the two cords within the ring, only far more complicatedly. We may fancy the whole field of stars as divided into successive pairs and tugging upon their respective cords, and we shall have, as nearly as may be, a copy of the experiment in question—except in one particular. This particular consists in the fact that the stellar strands, although eternally pulling, always stay crossed; *though always unwinding, they never become unwound.* Thus does our binary system not only fall to the maximal attraction, but also in a definite direction; the while simultaneously revolving around its center of gravity.

This mechanical principle is capable of unlimited extension, upward and downward. It applies as well to molecules as to stars, to cohering particles as well as to cosmic orbs separated by the full span of the universe. The sun's next door neighbor is *Alpha Centauri,* ten thousand times farther from him than Neptune, his outermost planet. Think of these two stars as we thought of the previous pair, think of any pair of stars, or of any combination of pairs or clusters of stars, in their relation to the sum of the universe, and there will be borne in upon you the realization that the whole body of the macrocosm is perpetually writhing within itself in the throes of equilibristic evolution. The physical universe is built on the principle of *action,* not stagnation; on that of *automatism,* not blind chance; *on perpetuity,* not finiteness.

Concentrating our attention on the solar system, we note that the planets revolve around the sun in (seeming) ellipses, that their *radii vectores* sweep over equal areas in equal times, and that the cubes of their distances are proportional to the squares of their periodic times. The problem before us is to prove that these phenomena are incidental to the normal operation of the *principle of the* *lever*—but, mark you, *not of a stationary lever,* but of one whose pendent weights are *in the act of falling.*

To begin with, what is the principle of the simple lever or balance arm? It is this: Suppose a bar to be supported on a pivot so as to rotate in a horizontal plane, then, in order that its arms, if unequal in length, shall balance, *the weights at the ends must be inversely proportional to those lengths.* That is to say, if one of the arms be half the length of the other, the weight on the shorter end must be doubled, if one-third the length, trebled, and so on.

And what are the *laws of falling bodies?* These are given by Ganot (Art. 49) in these words:

1. *The velocities are proportional to the times during which the motion has lasted.*

2. *The spaces described are proportional to the squares of the times employed in their description.*

3. *The spaces described are proportional to the squares of the velocities acquired during their description.*

4. *The spaces described in equal successive periods of time increase by a constant quantity.*

Suppose a bar, whose longer arm we shall call $R$ and its shorter $r$, be rotated horizontally around a stationary pivot, it will then descibe two *circles,* and, by geometry, we get the equation,

$$r : R :: 2\pi r : 2\pi R \qquad (1)$$

By our hypothesis, however, the *pivot is not stationary, but is falling,* and the ends of the bar are *not* describing closed circles in fact, but *coils of open spirals.* In still other words, the last two terms of our equation are, properly construed, "*heights fallen through.*" Under the second rule given above, then, our last two terms, in order to express the element of *time* instead of *space,* must be amended to read

$$\sqrt{2\pi r} : \sqrt{2\pi R} \qquad (2)$$

At this point, let us not forget that we are not dealing with a simple bar, but with a *lever,* whose arms, in order that they may balance, must be weighted *inversely as their length;* that is to say, a weight $R$ must be attached to the end of arm $r$, and a weight $r$ to the end of arm $R$. *Pound for pound,* then, the time required to complete the running of the smaller coil as compared with that required for the larger is inversely in the proportion of $R : r$. Amending our last equation, then, a second time, we get for the ratio of the "periodic times" of our two weights (or planets)

$$\frac{\sqrt{2\pi r}}{R} : \frac{\sqrt{2\pi R}}{r} \qquad (3)$$

whence, (parts of circles being to each other as their like parts)

$$r\sqrt{r} : R\sqrt{R} \qquad (4)$$

meaning,

*The periodic times of planetary bodies are to each other as their respective orbital radii (distances) into the square roots of those radii.*

Notice that this gives the ratio of the *simple* periodic times, not the ratio of their *squares,* which is logically better; but if you wish to identify the ratio with *Kepler's law,* all you need do is to *square* the separate terms, thus:

$$r^2\, r : R^2\, R \text{ or} \qquad (5)$$

$$r^3 : R^3 \qquad q.\,e.\,d. \quad (6)$$

Again, since under the third law given above, *velocities* are proportional to the square roots of the heights (here circumferences, or orbits), they are necessarily proportional in like manner with respect to the radii, or as

$$\sqrt{r} : \sqrt{R} \qquad (7)$$

But do not forget that these velocities are *inversely proportional* to the size of the weights carried, whence

$$R\sqrt{r} : r\sqrt{R} \qquad (8)$$

meaning,

*The velocities of planets are proportional to their respective distances into the square roots of their* OPPOSITES.

## THE LAW OF GRAVITATION

With this formula (8) before us, it is easy to derive the law of gravitation, gravitation being a form of ENERGY. Energy being proportional to the *square* of the velocities, we have, then,

$$R^2 r : r^2 R \qquad (9)$$

Now, there is this further rule regarding energy of motion, namely, that it *varies directly as the load*, and, as we have seen, the heavier load on a balanced lever is at the end of the shorter arm. We therefore multiply the first term by R and the second by r, obtaining,

$$R^3 r : r^3 R, \text{ or,} \qquad (10)$$

$$R^2 : r^2. \qquad q.\,e.\,d. \quad (11)$$

*Which is the law of gravitation itself*, namely, that *the energy of planets' motions varies inversely as the squares of the radii* (*distances*). This method really gives the *centrifugal* force, but as the centripetal is, by the law of reaction, *its equal,* the expression given is true for both.

## THE LAW OF AREAS

Kepler's second law declares that *the radius vector sweeps over equal areas in equal times.* This can be proven, on the principle of the falling lever, in this way:

Suppose a planet to describe a certain arc at perihelion in the space of one hour and, later on, an arc at any other part of its orbit, say aphelion, in a like space of time. Regarding the arcs thus described as arcs of circles, and the differing distances as radii, $r$ and $R$, the arcs, geometrically, will be in the ratio of

$$r : R \qquad (12)$$

We are not dealing with plain circles, however, but with the rotations of a lever. According to this principle, *what is gained in power is lost in velocity,* and *vice versa.* Moving the planet out to aphelion, therefore, modifies the *equilibristic lengths* of the arcs described in the inverse ratio of the radii, hence the arcs become,

$$Rr : Rr \qquad (13)$$

But the arcs thus related are *not plain distances, but heights, through which the weights* (which in the present instance are equal, being, indeed, the same planet) *are falling;* hence we now find the opposite arcs to be proportional, *dynamically,* thus

$$\sqrt{Rr} : \sqrt{Rr} \qquad (14)$$

But, by geometry, the *areas* of circles are as the *squares* of their circumferences *or of their like arcs.* In our ratio we have what we may correctly describe as *dynamical* arcs, incorporating within them, as they here should, the ideas of *geometrical* relationship, *equilibrium,* and *accelerative motion.* Squaring the terms, then, we get,

$$Rr : Rr \qquad q.\ e.\ d. \qquad (15),\text{ meaning,}$$

that *the areas of the respective segments at perihelion and at aphelion covered in equal times are equal.* Of course the rule holds good whatever parts of the orbit be compared.

Kepler's first law, namely, that planets travel in ellipses, is true only in the most superficial of senses. It is not true geometrically, dynamically, philosophically, or actually. Planets travel, instead, in *open elliptical spirals* of an exceedingly complicated design. Astronomers, indeed, acknowledge that the orbits are not reentering, inasmuch as the translation of the sun is well established; but they assume that, even if the sun were stationary, the planets would, nevertheless, continue revolving, and that these orbits would then veritably be closed curves. They picture the sun as possessing a unique rectilinear motion not primevally shared by his planets, and that the reason they accompany him is because he is *dragging* them along as a horse does a vehicle, whether or no. Thus have the Newtonians, in a way become habitual with them, underestimated the most significant and potential facts of the cosmos, facts, too, gained by their own herculean labor and expense.

Even though the bores, or calibers, of planetary spirals admittedly exhibit elliptical curvatures, the fact conveys little hint of the dynamical agencies concerned in their generation. Profoundly interpreted, each infinitesimal arc in each and every one of the planetary- and satellite spirals is a coördinated resultant of the equilibristic adjustments of the aggregate system; that is to say, every movement and turn of movement of the planets is a concomitant *effect of each member balancing itself against all the rest.* The solar system, in fine, is essentially *a revolving, composite lever.* To preserve the common equilibrium, when one member moves out from the sun another or others must, perforce, move in, and *vice versa.* These compensations automatically follow from the principle of balance, and extend to every part, even to the molecules and atoms that hang suspended in space; even, indeed, to the ether itself, if it be amenable to gravity. These compensating pulsations of the planets in and out from center have not escaped the keen eyes of astronomers, and have led to the empiricism and near-truth that the moment of momentum of the system preserves its uniformity. Unknowing the dynamical cause behind the phenomenon, they construe it as a teleological ordination, and point to it as the unimpeachable evidence of the so-called doctrine of the conservation of energy.

The fact that the planets have accommodated themselves all to practically one plane (that is, to a position of "flatness"), which, as I have shown before, is the condition of maximum stability, joined to that other significant fact that their orbits are near-circles, demonstrates either; first, that the planets are direct offsprings of the sun, or, second, that they have been members of the system so inconceivably long as to be in effect indigenous to it. It is otherwise with the comets and many of the asteroids, whose eccentricities of elongated orbits, high inclinations and retrograde motions are so many unmistakable proofs of their *alien* parentage and comparatively recent immigration. Like the bubble of a spirit level when first applied in test, a comet takes a series of pulsations across the field of equilibrism before attaining the state of relative rest that belongs to perfect balance.

### THE PATH OF THE SUN

Sir William Herschel (1738-1822), the illustrious discoverer of the planet Uranus, was the first to indicate the proximate point in the heavens toward which the sun is tending. That point astronomers refer to as the *apex of the sun's way* and now (erroneously) declare it to be "in the direction of the constellation Hercules, about 10° southwest of the star Vega"—not many degrees, indeed, from where Herschel himself located it. Since Herschel's day, numerous astronomers have adopted this particular field of research as their life-work, and hundreds of thousands of dollars have been expended in one form and another in this quest. Every labor of great magnitude such as this is should have behind it an adequate motive. Has this inquiry such a motive?

It is a lamentable thing to have to say, but the truth should out, that from the first day to the last that this search has lasted, scientists have had no motive other than merely to ascertain the bare isolated fact, entertaining neither plan, expectation, or hope that the knowledge will, or by any possibility ever can, prove *structurally* useful. Herschel has been dead for nearly a century, yet in all these years, for all the efforts made to reduce to exactness what he only adumbrated, there does not appear to have been a single illuminating suggestion put forward as to how the knowledge might one day be made helpful in the upbuilding of the science, be that knowledge as exact as ever it may.

Newtonians rely on the fundamental sophism that the motions of cosmic bodies are self-existent; that they are no more susceptible of explanation than matter's existence. Of our sun they say, simply, that he moves. They do not ask *why* he moves, for that riddle they gave up from the start, supinely supposing it beyond the reach of human penetration. All they dare to ask, or tolerate others asking is, "How fast and in what direction is he moving?" for this question involves no radical innovation which might in the end spell disaster to their cherished prejudices. It seems self-evident enough to me that the Newtonians, in denying the causation of the sun's motion, and in asserting, with ever increasing assurance and solemnity, that his course through the ether is unique, random, and uncontrolled by any organic unifying law, are guilty of a grave folly and are needlessly renouncing in advance the choice fruits of their arduous labors. The only conceivable value the knowledge of the sun's course and velocity can have to science and humanity, lies in its possible far-reaching correlations, *in its constructive potentialities.* A sun moving, as they assert, randomly, unimpelled, and undirected, can have, *per se,* no correlations and no structural significance whatsoever.

For all that, the practical astronomers, fired by the passion for physical accuracy for its own sake, are every day planning on an ever more and more ambitious scale to go over the same ground again and again, without any definite object in mind, it seems, save to see how near they may come to the previous marks. There is no way to test their accuracy, so far as they are aware, by final arbitrament of Nature, but only by indecisive comparison of their own results with those previously announced. In any case, all their labor goes for naught as long as their architects, the theorists, neglect and *refuse* to reform their ground plans so as to give structural place to the plethora of facts (never anticipated by the original architect, Newton) now promisculously encumbering the ground. Whatever incentives one may have to remaining unpersuaded, it must be patent to all that *a radical reformation of astronomical theory has become imperative.* What more likely way, I ask, than by giving to the phrase "UNIVERSAL *gravitation*" its plenary significance and genuinely universal applications?

The principle of the gyroscope is too well recognized to require extended discussion in this place. Rotation in one direction around an axis, under the law of action and reaction, must, and as a matter of everyday mechanics does, generate a reverse movement of the rotating mass in a larger circle around an extraneous point or axis. We are not merely hypothesising, then, when we predicate that the solar system, because of its integral rotation around an axis within the sun's mass, has a secondary motion of precession around just such an extraneous axis. Whether we can prove the deduction by an appeal to celestial phenomena remains to be seen, but the principle itself is not to be disputed.

Before stating conclusions, let me try to picture to the mind's eye of the patient reader the relation, as I conceive it, of the sun's orbit to the plane of the ecliptic, the Vertex, the pole of the ecliptic, the geographical pole, and the precessional circle.

Imagine, if you please, an enormous cone suspended in space, inverted, with an apical angle of 47°, and its upturned circular base, level with the ecliptic, possessing a diameter on the order of a thousand times the distance of Uranus from the sun. (See Fig. 4). Call the central point of this base (whose circumference constitutes the sun's gyroscopic orbit) the *Centrum* and from it drop a plummet to the apex of the cone some two trillion miles below, and call the plumb-line the cone's *axis.* Now this apex, be it understood, is the *Vertex,* as previously defined; that is to say it is the (blank) point in space toward which the earth (and our system) is being caused to fall by the composite of the stellar attractions—the Prime Resultant.

## THE SOLAR ORBIT

**Explanation**:—On account of the immense disparity in the dimensions, it is impossible to draw this figure to scale. Its purpose is to illustrate the relation of the earth's axial inclination and her general movements with reference to the sun and his orbit. The large circle is, of course, the Antarctic Circle of our Gravisphere and represents the sun's path, or rather the path of the center of gravity of his system. The next smaller circle denotes the orbit of the earth, but relatively enormously magnified. Arrow-heads in all the circles indicate the direction of movement. The positions A, $A^1$, $A^2$, $A^3$ show the earth at the instant of her vernal equinox, B, $B^1$, $B^2$, $B^3$ at our summer solstice, and so on. The celestial point of vernal equinox is found by sighting through the center of the sun from the center of the earth at the positions A, $A^1$, $A^2$, $A^3$. Unfortunately, however, owing to the fact that the sun's center is less steady in its course than the center of gravity of his system, the data of observation are not as consistent as they otherwise would be. The letter C denotes the center (Centrum) of the solar orbit and V the Vertex, the latter, however, needing to be pictured, not in the plane of the paper but about five inches behind it. Here the orbit is shown as a *closed* curve, whereas in reality it is a *spiral.* To obtain the correct conception the book should be held horizontally and then slowly lowered away from the eye, at the same time imagining the rotatory movements as in progress. Note that our view is from a point *south* of the ecliptic.

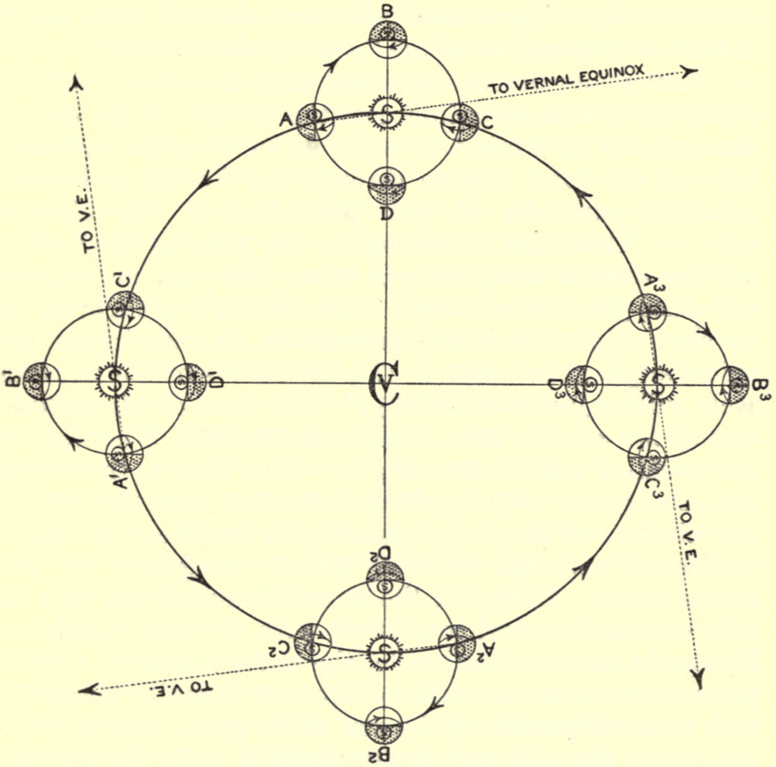
B
A
C
D
S
TO VERNAL EQUINOX
TO V.E.
C'
B'
D'
A'
V
A3
B3
D3
C3
TO V.E.
D2
C2
A2
B2
TO V.E.

Fig. 4

Station yourself in fancy vertically over (south of) the Centrum, but far enough away to obtain a bird's-eye view of the whole base of our imaginary cone clear to the circumference. Thus situated you are looking straight down upon the ecliptic and, sighting along the axis of the cone, you see the Vertex, or what is the same thing, its *place,* projected upon the far distant background of the northern sky. Mark that point and chart it well, for it is what astronomers call the *"pole of the ecliptic"*.

Leave your position now and with the winged and untiring feet of imagination run the circuit of the cone's base, gazing the while constantly down along the funneled sides of the cone, and on through the Vertex as before, watching carefully its new projection on the celestial sphere. This time, of course, the sky point of the Vertex will not remain fixed, but will move with your movement, and since you are running a *circuit* it will trace a cycle on the sky. More than this, inasmuch as, by description, the apical angle of our cone is 47°, the radius of the *celestial* cycle will be just half, or 23½°—*the same as the inclination of the earth's axis;* and its center will, of course, be the so-called pole of the ecliptic. The Vertex, therefore, you see, is, in a very significant sense, at once the pole of the ecliptic *and* the geographical pole, but it will not do to confuse it with the celestial points recognized by the astronomers. I suggest the name *Gravitational* pole as both descriptive and consistent with its dual character. Being the gravitational pole, the earth must, of course, perennially turn her center of gravity steadily toward it and, as a companion of the sun in his great orbital journey, keep her axis constantly parallel with the sloping sides of the cone, so that were her axis a hollow tube and your eye peering through it from the south end, you could always keep the place of the Vertex in your field of view and watch its projection upon the celestial sphere in the form of—*the circle of precession.*

To round out that circle requires, according to latest estimates, and provided the sun's velocity remain uniform, 25,810 years. Although hitherto attributed to false causes, this circle traced on the heavens by the earth's axis extended is a phenomenon known from the time of Hipparchus (150 B. C.). Important to remember is, that it is executed *contrary* to the motion of the hands of a clock, differing in this respect from the internal motions of our system, which are just the other way. You need to remember this when looking down, from the south, upon the cone base. Thus placed, picture the sun as revolving around this base contra-clockwise, because, as you will see on reflection, this movement will cause the Vertex, which serves as the common apex of two cones, to *seem* to revolve in the same sense. However, this will be true, that the "longitudes" of the two arcs thus being simultaneously described will be 180° apart, a circumstance of considerable value in orientating the position of the sun with respect to the stars, especially those nearest. Stupendous as the sun's orbit is—upwards of four million, million miles in length—his tether of about one-sixth this amount is still very far from reaching to even the nearest star. Whether we regard the Vertex or the Centrum as the solar hitching-post, it is a blank and not a star. For centuries astronomers have been scanning the heavens in search of an eligible star—*Canopus, Arcturus, Alcyone, Orion,* or even a cluster of stars—to tie the universe to, never once considering that the latter's *composite* attraction is stronger, surer, more flexible than that of any of its individual parts and, withal, invisible.

Here you may interpose the objection that the solar system instead of circling the base of the cone should be found at the Centrum. But your objection, to my mind, is not sound. According to my hypothesis, the solar system must *retreat,* in obedience to the principle of the gyroscope, and how could it possibly comply save by leaving its place? For the sake of definiteness, imagine the sun originally stationed at the Centrum, and then fancy the rotation of the system to begin around its own axis. By my hypothesis, this integral rotation would automatically cause a recoil which would carry the sun a little away from the center. The process thus begun, it would rapidly develope and steadily gain strength, the internal rotation would accelerate, and with that acceleration would come a corresponding increase in the gyroscopic momentum (i. e. centrifugal motion) and a consequent spreading out of the circle—to what extent Nature, herself, tells.

The whole proceeding may be likened to the action of a boy's peg-top, except that in one case the phenomenon starts from a state of rest and thereafter grows, while in the case of the top the reverse is true. When first thrown, as everybody well knows, the top does not settle at once on one spot, but gyrates at the outset in a widish circle, which gradually narrows until the peg seemingly becomes glued to one spot. Note, if you please, the inclination of the top in these introductory gyrations. Its axis extended does not remain parallel to itself, but trims out a cone, whose apex lies some distance below the floor, vertically under the central point of these exursions. Our earth is essentially a great top. While rotating on its axis it is likewise, as a member of the sun's great system, revolving around with him in his orbit, keeping her axis ever pointed toward the Vertex (the point below the floor. of the ecliptic) and trimming out its great cone once every (let us cling to round numbers) 260 centuries.

This is an appropriate place to emphasize again the fundamental distinction between Newton's explanation of precession and my own. Inasmuch as he had no physical ground for postulating the solar motion (a fact which was not really substantiated until a century and more after his death), he was obliged to treat the solar system as stationary and the earth, too, as stationary, in a certain sense. In his mind the earth's precessional oscillation resembles the top's behavior when, after spinning for a long time *on one identical spot,* it begins to nod and wobble before finally falling over upon its side. It is true that he did not attribute this nutation to loss of momentum, but to the differential attractions of the sun and moon upon the equatorial ring. Nevertheless, everyone must perceive that the causes Newton assigned were diurnally, monthly, and annually *complete;* and it was highly inadmissible for him to assume out of hand that the effects could be otherwise than swiftly cyclical to correspond. Obviously, my conception of the gyroscopic orbit steers clear of Newton's error and accords perfectly with the *protracted* character of the phenomenon in question.

Having thus carefully studied each feature in detail, let me request the kind reader to station himself again at his old vantage point vertically above (south of) the Centrum and take a comprehensive view of the whole plan. There you see the sun (more specifically, the center of gravity of the system) pursuing his gyroscopic course exactly along the rim of the cone's base, in a direction contrary to the motion of the hands of the clock. As thus he travels, his planets continuously revolve around him, the earth in 365¼ days, and the other planets in their different periods—not with the left-hand motion of the sun, but *vice versa.* Note, also, that the axis of the earth always parallels the sides of the cone, so that, no matter at what point she may be in the big orbit, her axis continually maintains its inclination to the ecliptic or cone-base of 23½° sensibly unaltered. In thus swinging around a great circle, while all the time pointing to a (relatively) fixed point, to-wit, the Vertex, the latter is projected against the celestial sphere where it outlines the precessional circle, which is, in fact, the base of another cone, reversed, whose apex our Vertex is also.

So minute is the range of the annual revolution of the earth around the sun relatively to the major orbit of the latter, that you can readily see why the earth's axis, year by year, should remain (almost) parallel to itself, the secret of our change of seasons. The slight departure from parallel that it *does* suffer in one such revolution is, of course, according to the new hypothesis, reflected in the alteration of the projected position of the Vertex on the precessional circle traced on the sky.

Observe, furthermore, that in revolving around the sun, the earth is obliged to pass twice each year across the precise line of his path, once in front of him, when she is on her way out, and the second time behind him, when she is on her way in. The first of these two points is known as the *vernal equinox,* and the second as the *autumnal equinox.* When the earth is at her outermost point, you will see that her Arctic region is pointed sunward, so that then we of the north have summer, while our winter solstice occurs when the earth is innermost.

In the very nature of things, with every star in movement, there is no such thing as an absolutely fixed point or an unalterable direction. Astronomers understand this (though strangely forgetful of it at times!) and do the best they can, under the circumstances, by choosing the most stable points and using them for reference. As important as any of these is what is known as the *celestial* vernal equinox, and it is that sky point where the center of the sun (to the eye of an observer supposed at the center of the earth) crosses the plane of the earth's equator. In my theory this occurs at the precise instant when the center of the earth, being then in advance of the sun, cuts across the line of his orbit. Every year the astronomers spare no pains to locate this point with all nicety possible, in order to keep accurate track of general changes of position.

It is important to remember that the celestial vernal equinox *does not remain fixed* with reference to the stars, but progresses westwardly around the zodiac. To understand why, you will readily perceive that in traveling around the great circuit and looking back once a year past the sun, just when the centers of both are on the orbit, the latter will be necessarily projected just as many degrees to the west on the celestial circumference as both have advanced in the same time in their common orbit. This annually executed arc has been measured with the most refined nicety and has been found to be 50″.2. In other words, the sun covers an arc of his orbit 50″.2 in length each year, and at this rate should complete one lap in 25,810 years.

## THE ORBIT AND VELOCITY OF THE SUN COMPUTED

Inasmuch as, by hypothesis, the forward motion of the system is due to a definite and single force, to-wit: the Prime Resultant, we might be justified in concluding, without further corroboration, that in one year the earth, from one vernal equinox to the next, advances along the main orbit exactly the diameter of her own—a conclusion which, were we to apply the principle of falling bodies, associating with it the principle of the lever, would prove generally true of all the rest of the planets. However, there is another chain of evidence to which I wish now to direct your attention which correlates these several data, namely: the velocity of the earth in her orbit, the length of the arc, the degree of curvature of the arc, the length of the diameter of the earth's orbit, the principle of falling bodies, the velocity of the sun as deduced from the direct study of the proper and the radial motions of the stars, and, finally, the parallactic motion of the Vertex.

Given the length of the arc of a circle in degrees and also in linear measure, it is only a matter of high-school mathematics to find the total length of the circumference and, from that, all the remaining functions of the circle. Again, if we know the length of an arc and the amount it deviates from its tangent (technically called the curvature), we can, by a simple formula, ascertain the radius in the first instance, and so on to the rest. In the case under consideration we virtually know these two things: the arc's length, and its curvature in miles. The latter is quickly ascertained in this way:

If you have been following this somewhat intricate explanation closely, you should be able to see with little effort, that, inasmuch as the sun has at the instant of the *second* vernal equinox failed to get back fully into line with the same star it was in line with at the preceding equinox, the earth must continue on in her orbit beyond her equinoctial position until the old star, sun, and earth are all brought again into alignment. Astronomers tell us that it takes 20ms. 23 secs. for the earth to move far enough in her orbital journey to correct this discrepancy —this *curvature of the arc.* Now, the earth's average velocity being known (18.5 miles per second), to reduce this curvature to terms of miles we need only multiply this quantity by the number of seconds of time to obtain the answer, 22,625 miles.

As said before, given the length of arc in *seconds* and the curvature in *miles,* it is easily possible to ascertain the radius of the circle. The rule, stated in the form of an equation with the initial letters of the things referred to (See Young's Genl. Astr., Art. 420), is:

$$c : a : : a : 2r$$

Now the length of the radius in terms of degrees of circumference is called a radian, and is known to be 57° 17′ 44″.8, or 206,264.8″. Substituting this and our other values in the equation given, we have,

22,625 (miles) : arc (in miles) : : 50″.2 : 412,530″ which, being reduced, yields

$$\text{arc}=185{,}977{,}500 \text{ miles},$$

the meaning of which is, that in one year the center of mass of our solar system travels exactly the width of the earth's orbit, as measured along the equinoctial colure, AND THAT THIS COLURE MARKS THE LINE OF THE SUN'S PATH. Choosing round numbers, we ascertain by simple computation the length of the sun's orbit, considering it as a closed curve, to be 25,810 x 186,000,000 miles, or 4,800,000,000,000 miles, its diameter 1,530,000,000,000; the axis of the cone from Centrum to Vertex 1,760,000,000,000 and from the Vertex to our sun (that is to say, the stem of the Prime Resultant) 1,918,000,000,000 miles. Finally, there being 31,557,000 seconds in a year, the sun's velocity is found to be just a trifle short of six miles per second.

"But six miles", you will say, "is only about half the actual velocity of the sun as found by the direct methods, how do you account for the balance?" I will answer you. Hitherto in this discussion I have, for the sake of simplicity, ignored the very material feature that all this while the plane of the ecliptic, though remaining sensibly parallel with itself, is *falling,* keeping pace with the fall of the system. In other words, the sun is falling vertically just as fast as it is "gyroscoping" laterally; or, to borrow the parlance of the astrophysicists, he has both a "proper" motion and a "radial" motion. You may retort, that in such case he is travelling along the hypothenuse, hence can be going only about 8.5 miles per second. This is true enough, but considering the two velocities separately and then adding, which I understand to be the practice of astronomers, the total comes to 11.8 miles. In any case, the net result is so close to that obtained by the laborious practical methods that either result might fairly be cited in corroboration of the other. Besides, it ought not to be presumed that we have exhausted *all* the possible motions of the sun, and some margin should be allowed for future developments.

According to Newcomb, the pole moves 20″ per annum on the scroll of the celestial sphere. Taking the sun's annual movement of 186,000,000 miles as the base line, the question arises as to how distant the Vertex must be to possess this parallax, or in other words, to make the distance 186,000,000 miles subtend an angle of only 20 seconds. To ascertain this we need simply divide the 186,000,000 by 20 and multiply the quotient by the number of seconds in a radian, yielding as a result, 1,918,000,000,000 miles, *which is precisely the same value we found by the other process.*

Again, it may be interposed that if, indeed, the system be falling at the rate specified, it would in the precessional period fall a sheer height equivalent to the full length of the sun's orbit—practically twice as low as the Vertex. This deduction, also, is right,—if one remembers that he is speaking only of absolute space. But the vertex is no more riveted to one spot than a horse drawing a vehicle. It is merely the crossing place of gravitational strands that, real and powerful though they are, are yet as imponderable, as elusive, as mobile as the rays of light itself. The Vertex, in fine, is a will-o'-the-wisp, beckoning the system on and on forever, and, indeed, the Gravisphere itself should be conceived of as in the process of falling.

If the reader has acquired the impression that I identify the vertex with the center of the stellar universe, he is mistaken. There may be such a center, perhaps; but if so, it is as shifting as the clouds, since all things are in motion. The Vertex is for the system a *proximate cen-*

*ter* only, just as the earth is for the meteors that fall in upon it. The garden of the sky, indeed, is crowded with these umbels of forces carrying, perched on their stems, their planetary efflorescences. Beyond that Vertex is another far more distant, beyond that again, another more distant still, and so on, rising higher and higher in scale, and bearing upon their twigs systems, and upon their branches systems of systems of worlds. To my mind, the flatness and the well-proved depth of the disc of the Milky Way eloquently testify that it is a gravitational unit in a mightier invisible universe, invisible only because the light of its component stars is drowned in the vast sea of space. As such a unit, of course, the Galaxy should rotate around an axis in search of equilibrium, and it appears that astronomers have already detected some indications of such rotation! Underlying the whole structural scheme of the macrocosm, as under the humblest habitation of man, lies the great principle that Newton took such pains to eliminate—EQUILIBRIUM.

## THE STAR STREAMS SO-CALLED

The reader may infer from what has just been discussed that the star streams that Kapteyn was the first to call attention to, may find their explanation in this principle. Such is not my own opinion. This phenomenon of star-streaming is, like the daily motion of the heavens around our earth, illusory. It is only apparent. It arises from a misguided attempt on the part of astronomers to generalize from data gained by observing from one moving body another moving body with reference to a third moving body, all of whose velocities and distances, relative and absolute, are highly conjectural, and, in the case of the earth at least, misconstrued. No! whoever cares to play the role of skipper of this good ship, Earth, and in imagination will take his stand at her south pole and sail her around the sun's orbit a voyage or two, watching the while the stars on shore, will soon come to realize that the supposed streams are but the optical effect of our change of position.

Inasmuch as the stellar motions are by astronomical practice and necessity referred to the center of the sun, and *that* in turn to the vernal equinox, we do not need to confuse ourselves by attempting to combine in our thoughts the earth's annual motion of revolution with the stellar motion. We can, instead, more easily and satisfactorily imagine the earth as always in vernal equinox, that is, sailing straight ahead of the sun on his orbital path. The patient student, who will expend the necessary effort in acquiring a knowledge of the methods and results of practical astronomers along this line, will have reason to marvel at their perseverance and accuracy when he finds how remarkably they are corroborated by the logical deductions flowing from these theories.

## VI

## THE AUTHOR'S THEORY OF THE TIDES

IN this chapter I hope to convince the reader that tides are not created in the manner depicted by Newton, that is to say, in antagonism to the principle of equilibrium, but by a process exactly the reverse.

In the diagram (Fig. 5) let E represent a planet endowed naturally with the property of gravitation. It consists, let us say, of a solid ball 10,000 miles in diameter surrounded by an envelope of water five miles in depth, and, as an aid to the imagination, suppose this water frozen to a depth of one mile. Let us now bring into touch with E a second body, M, which has no seas and which, in the outset, possesses no gravitational power. Under these conditions E, of course, will not be in the least affected by M's proximity. But suppose we had a method whereby, as by the turning of a tap or switch, we could charge M with as much of this force as we pleased, and let the current be then turned on. What would be the natural effect upon E? Surely its solid part would immediately begin to sink in its own seas and finally rest upon the inner surface of the ice crust (Fig. 6). In other words, the tidal action of M on E would be to depress the seas intervening between them and not to elevate them there at all. Now, if you please, turn on the discharging tap and see what will happen next; obviously the planet E will return to its original condition.

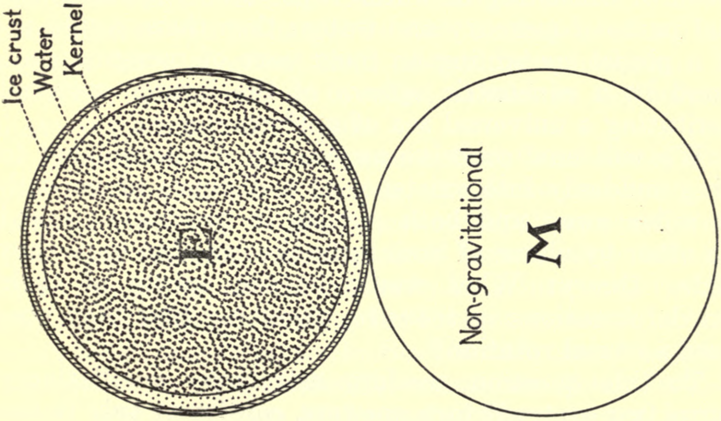
Ice crust
Water
Kernel
E
Non-gravitational
M

Fig. 5

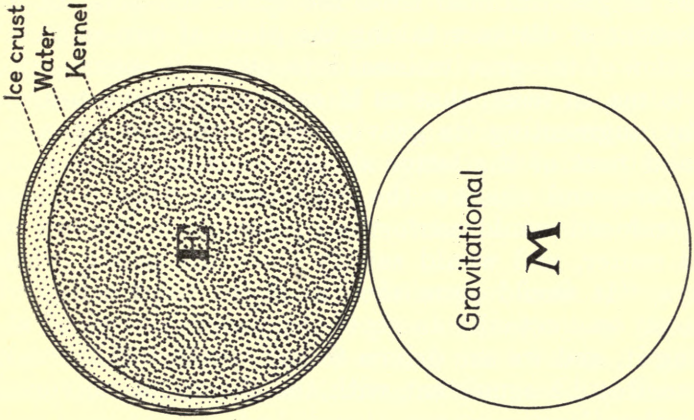
Ice crust
Water
Kernel
E
Gravitational
M

Fig. 6

The same phenomena would have occurred, in like sequence, had we imagined the body M approaching E *through a great distance.* M might then have been postulated as gravitational from the start, the same as E, the element of distance taking the place of our artificial regulation of the gravitational intensity. It seems quite clear to me, at least, that as M came nearer and nearer, thereby augmenting its gravitational influence upon E, the solid part of the latter should react precisely as it did before, and shallow the sea between them. Tides thus produced would conform in principle to the law of lowest center, and would satisfy Darwin's plaint, when he says, "It would seem then as if the tidal action of the moon was actually to *repel* the water instead of attracting it, and we are driven to ask whether this result can possibly be consistent with the theory of universal gravitation."

Let us consider a second illustration: Imagine the universe blotted out save for a single cloud of aqueous vapor of, say, the same mass as the moon; then, under the principle of gravitation, the cloud would eventually condense into a watery sphere. Suppose, again, that instead of consisting of water vapor alone, it comprised equal parts of mercury and water; then there would result a planet containing an inner core of mercury, and, around it, a concentric sphere of the lighter material constituting a universal sea of uniform depth.

We will now conceive an exactly similar planet to spring suddenly into existence at a distance of ten million miles away and both planets to gravitate toward each other by virtue of their mutual attraction until they collide. Query: What would be the nature of their tidal deformations *in transitu,* assuming that they possessed *no* axial rotation?

To this question, modern astronomy vacillatingly returns two contradictory answers, consistent only in the respect that both are equally inimical to the principle of equilibrium; which, indeed, is precisely what they are meant to be. One of these answers is Newton's own, namely, that inasmuch as the power that causes the tides resides in the fact of *rotation,* there being in this case, by premiss, *no* rotation, there could be no deformation at all; hence the two spheres would arrive at their point of impact as perfectly spherical as when they began falling.

The alternative answer is that of the hypothesis of statical tides, which astronomers make use of without hesitancy whenever it suits their purpose, in spite of its gross logical inconsistency. This view asserts, that the spheres in question would elongate in the direction of the line of descent, so that by the time they reached the point of collision they would somewhat resemble row-boats meeting bow on.

In order to expose the fallacy of both these views, let us try the time-honored plan of picking up the other end of the skein, and working backwards. Suppose, then, the collision to be a thing of the past and the resultant body to have had time to compose itself, as it naturally would, into a new sphere in all respects like our two original ones, only, of course, twice their size. Conceive this major sphere to be cleanly severed in half, and the divided parts to be gently removed from each other to their original separating distance. Without doubt, by the time they arrive at those extreme points, the two hemispheres will no longer be such in shape, but will necessarily have acquired their aforetime sphericity. The question then arises as to what should be the intermediate or transitional shapes.

May it go without argument, that the chain of transformations, going and coming, should be the *same,* only in reverse order? If this be conceded, then, according to Newton's idea, the hemispheres *immediately* following their sundering should *instantly* leap into spheres then and there, without waiting for further removal. On the other hand, according to the Statics, they should, instead, but *quite as spasmodically,* reassume their boat-like forms, and from then to the end of the outward journey gradually exchange these for the spherical. These, to my thinking, palpable *reductios ad absurdum,* effectually refute both these classical *anti*-equilibrium hypotheses.

It remains, however, to vindicate my equilibrium solution affirmatively by showing that, under it, the chain of transformations, to and fro, is not only the same (save, of course, as to the fact of necessary reversal), but that all the transitional shapes it presupposes can consistently be figures of equilibrium. All this, I hope the reader will perceive is assured and attained when we conceive that, in being removed outward, the hemispheres imperceptibly take on forms more and more *gibbous,* simulating the phases of the moon from first quarter to full, while in the contrary direction the spheres become less and less so, imitating the phases between full and last quarter. Everyone should be able to see for himself that the nearer the minor spheres approach each other, the more does the water seek passage to the rear, as though in fear of being caught ''between the bumpers'', while in going the other way, things are just *vice versa.* In Fig. 7 are shown, in juxtaposition, the three sets of transformations in the order above described.

Speaking specifically of the earth, then (though the principle applies universally), her tides are caused by a conflict between two ruling gravitational forces, namely, (1) the integral attraction of the earth upon her own mass, and (2) the extraneous attraction of the sun; the first seeking ever to concentrate her heavier substances at her center and to deploy the lighter on the outside, the latter ever striving to compel her to recognize the sun's rival power and advance her heavier parts toward him. Were the earth solid clear through, as the moon appears to be, she would turn the same face to the sun continuously, but having great mobile oceans, she compromises by shifting them from in front of the sun, thus giving her center of gravity, as it were, a chance to make obeisance to him.

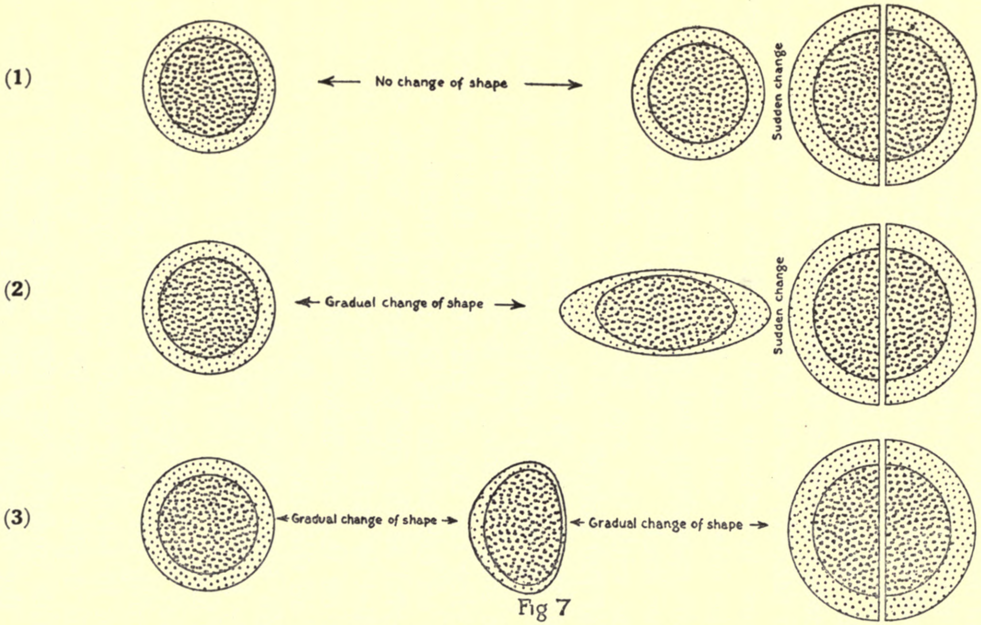
(1)
No change of shape
Sudden change
(2)
Gradual change of shape
Sudden change
(3)
Gradual change of shape
Gradual change of shape

Fig 7

Illustrating the tidal deformations of a non-rotating, moonless, water-mercury planet as conceived respectively (1) by Newton, (2) by the Advocates of the Statical Theory, and (3) by the Author.

## COMPUTATION OF THE TIDAL FORCES

It will be remembered that, according to Newton's idea, the waters making up the tidal mounds are construed as being drawn thither *obliquely* from the rounded sides of the earth; whence he argues that the tidal forces of the sun and moon do not vary in accordance with the rule of inverse squares, as the law of gravitation has it, but of the inverse cubes. As a result of this hypothesis, he estimated the ratio of the sun's effect to that of the moon as (about) one to four. If *we* are right, however, in our new hypothesis that the tides are *acts of equilibrism,* the solar and lunar tidal forces vary, not according to the exception, but strictly *according to the letter of the law* itself. Thus calculated, they vary as 180 to 1, this time with the sun having the advantage—a total change of 720 points!

Knowing as we do the relative masses of the earth and sun (1 to 332,000) and the earth's radius as compared with the solar distance (1 to 23,000), we can easily find by applying the law of gravitation that the earth's attraction on her oceans is, in round numbers, 1600 times as powerful as the sun's. Here, then, is the measure of the conflict of authority between the earth's integral attraction on the one hand, and the sun's disturbing attraction on the other; the former commanding the oceans to remain where they are, the latter ordering them to give way and let the earth's center of gravity step forth to greet him.

What we want next, now, is to get at some way of determining the *quantum* of this force in tangible terms. Why not in terms of mean ocean depth? As stated before, this depth is given by Murray as 12,480 feet. Dividing this quantity by 1600 then, gives 7.8 feet, representing the intensity of the sun's protest against the earth's own disposition of her ocean waters—though it may not, indeed, actually dislodge them, seeing that the earth, in the course of her rotation, keeps presenting a new face to the sun before his effect at any one point can arrive at completion or become permanent.

The solar tide being thus found to be 7.8 feet, to find the lunar tide we simply divide this amount by 180, yielding only a trifle more than a *half inch.* These figures, let it be noted, are substantial quantities, derived as they are from well-ascertained relevant data, and may not fairly be compared with Newton's estimates, based as they were on the spurious standard of the thickness of the equatorial ring. If a comparison be desired at all, the fair and logical way is to contrast my results with the 1-20 and 1-80 inch tidal measures for the moon and sun respectively, which, by parallel computation, I derived in a previous chapter.

## THE CAUSE OF THE EARTH'S DIURNAL ROTATION

It has been previously demonstrated, not only by the author's original arguments, but by the quoted admissions of such orthodox authorities as Sir Robert Ball and Sir John Herschel, that Newton's premises presuppose a miraculous origin of the earth's axial rotation and, what is more, provide no recuperating source to make good future losses. As if this were not taxing human credulity enough, we have been further taught: first, by Newton and Herschel, that the equatorial ring is being centrifugalized throughout the ages by this mysterious power; second, by Kant, that the rotation is being slowly destroyed by the friction of the tides; thirdly, by Ball and the rest, that all the energy that goes into the lifting of the tides flows from this same store of unearned momentum; and, lastly, that, marvel of marvels, the historical records of some five thousand years of eclipses inform us that, in spite of all these monstrous drains, the earth's day has not lengthened by so much as a hundredth of a second of time! Truly, celestial mechanics as taught by our "great scientific institutions" is quite as far above the heads of common mortals as Dr. Abbot says.

Counting myself as one of this plebeian caste, I confess, without any sense of shame, my simplicity in supposing that the earth's axial rotation had a *dynamical* origin, that it is being spun by a live power, and that the much taking of something from nothing, though possible to Newtonian imagination, will never content my banker.

That some physical cause lies behind the earth's rotation is *axiomatic;* and what cause more eligible to this purpose than this very phenomenon of the tides, superinduced as they are by that great cosmic force—gravitation? Where can power be more effectively applied than at the *circumference* of the fly wheel? Has it never occurred to you before, that Newtonianism has found no use for gravitation save as a *restraining means—to leash* planets and *retard* rotations? Given this unique, this all-sufficient creative energy, modern science has systematically resisted its logical development. Like the unworthy servant in the parable, it has buried its talent.

Here we have the precise elements requisite to account for the earth's diurnal rotation. In Fig. 8, let AB represent an arc of the earth's orbit, along which she is being hurried by the vortical action of the Prime Resultant, and E, our planet itself (the direction of the movement in each case being shown by the arrows). As previously explained, the tidal action of the sun at the point indicated by x is to *drive back the oceans* with a strength equivalent to 1-1600 of their weight; it is as if the sun were applying a very powerful brake, or as if he were blowing a strong blast against that side, causing the solid kernel to trip, as it were, and roll over and over upon its face, like a barrel on an incline. Or, as some might say, the principle is rather that of buoyancy, the kernel being "lifted off its feet", as by a sudden rise of water, rendering it perennially unstable against the pull of the Prime Resultant. A stately ship, our Earth, driven by wireless power from the stars; herself the compass, humanity her passengers, eternity her port!

If we care to, we can imagine a beginning to this process from a previous state of rest, and picture to ourselves a gradual acceleration of the movement until, like a fly-wheel responding to its engine, the planet attained the *uniform* velocity it now *seems* to possess. However,

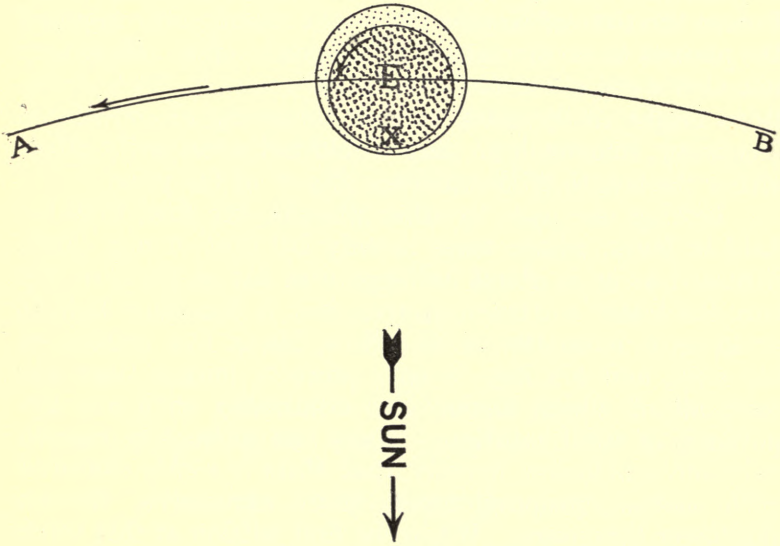

Fig. 8

the applied forces are not *absolutely* uniform the year through, for not only is the earth nearer the sun at perihelion than elsewhere in her orbit, but that place happens also to be the position of the winter solstice, when a greater ocean expanse is exposed to the sun's tidal influence; besides, the earth travels faster in her orbit then than at other times. For these reasons, the spring days (24 hours) must be a few seconds shorter than those of autumn, but whether our chronometers are reliable enough to register these nuances is doubtful. Before the time of Kepler the world mistakenly supposed the planets to revolve at uniform speed. Why, then, may not also *axial* velocities periodically vary? Such variations might easily exist without incurring observational discovery, inasmuch as they would not necessarily affect either the length of the *average* day or of the year.

Lifting our eyes to other planets, the first they behold is Mars, whose mass is only 1-9 that of our earth. Situated as he is about half again as far as we from the sun, the latter's attraction upon him is less than half as great as it is on the earth. Now, Mars, too, rotates on his axis, and his day is only slightly longer than our own, all of which harmonizes admirably with our hypothesis of tidal rotation. There can ultimately remain only one conclusion, namely, that *Mars is richly endowed with oceans,* proportionately more expansive, though shallower than ours. When the first edition of this work appeared in March, 1912, it was difficult to discover in the books any testimony in support of such a deduction. In fact, the reports were almost if not wholly the other way, making the planet out to be a veritable desert. During the last two oppositions, however, overwhelming evidence of a contrary nature has grown apace, some of which will be adduced in a later chapter. As for the axial rotations of the sun and Jupiter, with their peculiar problem of equatorial acceleration, and the rotations of the other planets in general, these must be postponed to a later chapter.

## THE TURNING FORCE COMPUTED

Before leaving the subject, it may be well to ascertain the degree of this buoyancy, or, if you prefer, the weight of the pressure of this brake.

The sun illumines only one-half of our planet at a time, and on that half he does not shine all over vertically, but mostly obliquely. Accordingly, in estimating his tidal action we may average it up as affecting only one-fourth of the ocean area at one time, but this much with maximum effect. This area is given by Murray at 140,000,000 square miles, of which the fourth part is 35,000,000 square miles. A sheet of sea water (63 pounds to the cubic foot) 7.8 feet in depth (the solar "tide"), extending over this immense expanse would weigh 240,000,000,000,000 tons, an amount strangely identical with my former estimate of the intensity of the earth's attraction upon the moon. Converting this into horse-power, according to our chosen formula, it becomes quite evident that the earth is not turning on its axis simply "because it cannot stop a motion that never was started", but because Nature intelligently supplies a *quarter-quadrillion-horse-power engine* to do the work. This, too, in addition to the coöperation of the Prime Resultant, pulling the earth along in her spiral orbit.

## THE MOON'S RELATION TO THE TIDES

Although Newton estimated the ratio of the solar and lunar tides as 1 to 4, modern computation places it at 1 to 2.25. Were either of these ratios true, it is hard to understand why no trace of a solar tide has ever been detected. To say that the lesser merges in the greater, even though the circumstances for their separate existence are at times most favorable, is only a subterfuge. The absence of such a double set of tides is, however, easily understood under my theory, for the lunar tide is reckoned at only 1-180 of the other relatively, and only a half-inch absolutely—far too insignificant to show.

A more important problem, however, is: *Why do the passage of the moon and the appearance of the tide, even* *though the latter* is *some eight hours in her wake, exhibit such a singular correspondence in their schedules?*

To begin with, I urge upon you, as an honest juryman, not to ignore the moon's sound *alibi.* She has never yet been discovered *in flagrante delicto.* Countless human eyes, including Darwin's, can testify that at the time she is accused of having lifted the tide in the mid-Atlantic, she wasn't there at all, but mid-over the Pacific. She is the victim of incriminating circumstances, perhaps, but she is immaculately innocent. Darwin, you know, accused her even of *repelling* the seas under her, for which he had better cause; but in the end he preferred to believe her guilty of the crime alleged, in shameful disregard of the evidence.

The whole mystery dissolves away with the discovery of the *true* tidal cause. Without being able to fathom the physical reason, astronomers have discovered that changes of momentum in this or that member of a cosmic system, whether orbital or axial, are invariably compensated by reverse changes elsewhere. They call this "the law of conservation of moment of momentum". With them it is only an empirical fact, an arbitrary provision of Nature's, dictated neither by discoverable reason or necessity.

Our present inquiry as to why the moon and the tidal crest keep pace, affords us an excellent opportunity to emphasize and illustrate the advantage of the principle of equilibrium over the denial of it as a key to the structure of the cosmos, and to point out the superiority of physical causation over cryptic abstractions. The studious reader who has done me the honor to read thus far must now be as familiar as myself with the conception of what a "gravitational unit" is, and how our binary earth-moon system maintains its balance, progressively, in the face of all adverse outside attractions. One—the chief—disturber of this equilibrium is, of course, the sun. By virtue of his differential attraction upon the kernel of the earth and her seas, the planet is obliged to redispose her mobile parts—to wit, her oceans—in such a way as not only to trim her own balance, but *that of the little system of which she is the main cog.* The question is, whither shall the waters squeezed out from under the sun go, so as restore the system's shaken balance? Certainly not to the spot *under* the moon, for that would only be making matters worse by still more overweighting that already overweighted side! No, the natural way is for the migrating waters to heap themselves up at two points on the surface *equi-distant from the moon and from each other,* forming together, as it were, the three corners of an isosceles triangle. These locations, of course, are *ideal* rather than actual, inasmuch as the moon, because of her monthly revolution, is constantly changing her angular position relatively to the earth and the sun, thus dynamically complicating the phenomena themselves, as well as the mathematics of them, beyond human unraveling.

It is important, in this connection, to avoid the mistake of supposing that the sun's displacing power upon the waters is necessarily always uniform. Were this true in fact, it would but cloud the principle involved. The principle is that the earth must maintain her own and her system's equilibrium, and so she reacts to the attraction only to the extent required by the conditions of the moment. For instance, when the sun is mid-over either ocean, his effect is at a maximum, and when he is looking down upon the continents, at a minimum; likewise, in winter, when he is farthest south, where the oceans are twice as expansive, the tides are in general higher than when he is north of the equator. The position of the moon in her orbit is another factor that rules the heights of the tides. When she is in line with the earth and sun, the system is top-heavy, and needs more ballasting than when she is elsewhere, hence it is then that we have our "spring" tides; but when she is at quadrature, the contrary is the case, and we have "neap" tides; and so on.

This principle of what may be called *tidal equilibrism* furnishes the sufficient explanation of the singular movements of the inner satellites of Jupiter and of Saturn, described by Sir John Herschel in Articles 542 and 550, respectively (*Outlines of Astronomy*):

> An extremely singular relation subsists between the mean angular velocities or mean motions of the three first satellites of Jupiter. If the mean angular velocity of the first be added to twice that of the third, the sum will equal three times that of the second. From this relation it follows that if from the mean longitude of the first added to twice that of the third, be subducted three times that of the second, the remainder will always be the same or constant, and observation informs us that this constant is 180°, or two right angles; so that the situation of any two of them being given, that of the third may be found. * * * One curious consequence is, that these three satellites cannot be all eclipsed at once; for, in consequence of the last mentioned relation, when the second and third lie in the same direction from the centre, the first must lie on the opposite. * * *
>
> A remarkable relation subsists between the periodical times of the two interior satellites of Saturn and those of the two next in order of distance; viz., that the period of the third (Tethys) is double that of the first (Mimas), and that of the fourth (Dione) double that of the second (Enceladus). The coincidence is exact in either case to about 1-800 part of the larger period.

That the atmosphere should be affected by tides in much the same manner as the hydrosphere goes without saying, but on account of its invisibility, its tidal behavior cannot be so exactly investigated and defined. One point of this relationship is revealed by the observed fact that when the ocean level is low, the barometer is always higher than normal. It is atmospheric tides that constitute the chief cause of trade winds, but I shall not weary the reader by discussing this collateral subject in the present work.

## TERRESTRIAL MAGNETISM

By substituting, in theory, tides of depression for lifting tides, we not only gain in frictional effect, but we likewise transpose the locus of it to the floors of the oceans instead of to their coasts. On the other hand, I have given reasons to justify the deduction that the metals, being the heaviest substances, are mainly centrally located within the earth, and ranged along its axis. The semblance of the earth, therefore, to a helix and core, taken in connection with the dynamical effect of the tides, leads easily and naturally to the conclusion that *the earth's magnetism is tide-induced.* If added proof be demanded, it is to be found in the remarkable coincidence of the magnetic needle's variations with those of the diurnal movements of the sun and moon, and, quite as remarkable, with the change of seasons as well. Indeed, on careful investigation it will be found that whenever the water is severely shaken in the ocean bowl, by tides or by any other cause (solar explosions, for instance, which temporarily unbalance the earth as well as all other bodies in the system), extraordinary electrical phenomena are certain to follow. Heretofore, attempts have been made to connect the needle's variations with the fluctuations of the solar radiation, but unsuccessfully, because of the conflicting fact that the moon, whose radiation is comparatively nil, has been found to exercise a similar magnetic influence rivaling the sun's own. Orthodox astronomy has not dared to broach this tidal explanation, because it would involve too brazen a drain on inertial momentum; but the explanation becomes fully available under my own theory of gravitational centrifugal motions.

According to this logic, the earth's poles, being the termini of the supposed "core", should be the centers of greatest electrical activity, the charge passing from one or the other of them through the atmosphere, along meridianal lines, to the opposite pole, thereby completing the circuit. This surmise accounts at once, and equally well, both for the northern lights, or *aurora borealis,* and for the direction and deflection of the magnetic needle, besides offering a most alluring field for speculation as to the possible future exploitation of another natural resource.

## THE COMETS

Beautiful though some of them are, the comets have ever been regarded by the ignorant as forerunners of disaster; and since disasters have a way of occuring right along, the comets have not failed to sustain their unenviable repute. Scientifically, they are generally looked upon as strays from neighboring systems, and this character they undoubtedly possess, notwithstanding that many of them have succeeded in insinuating themselves as permanent occupants of our solar hearth. Their manners it is that proclaim them strangers; they move eccentrically, redden when they near the sun, and presently turn tail and hurry away, perhaps never to return. But what, in truth, are they, and why do they behave as they do?

Imagine two bodies of equal mass away off in space and separated from each other by a considerable interval, and, midway between them, a cube of lead and a similar cube of ivory glued firmly face to face. Under these circumstances, clearly the bi-cube would take up a neutral position, disposing its longer axis at right angles to the line joining the attracting bodies. Suppose, now, one of the planets to remain stationary while the other is violently projected straight toward it. In this case, according to my interpretation, the bi-cube will incline its lead end toward the nearing planet and, by the same token, turn its ivory end toward the stationary one, more and more, until, finally, the long axis instead of remaining transverse, will run parallel with the line of force. An unreflecting person, watching the whole proceeding, might misinterpret this action of the double cube as attraction upon the lead and *repulsion* on the ivory; but we know better than that, because we know that ivory *by itself will fall* as well as lead, so it too must be *attracted.* Indeed, had we mated the ivory cube with a cube of cork, instead of lead, it would have enacted the same role as the lead. In other words, differential attraction due to variation in density creates *the illusion of repulsion.*

Let us carry the experiment a step farther and imagine, in lieu of the bi-cube, a sealed tube many miles in length, nearly filled with equal volumes of a dozen mutually insoluble liquids, like mercury, water and benzol, and repeat the first process in the same order. Can you doubt for a moment that the tube, like the bi-cube, will at first orientate itself transversely to the course of the equal attractions, and, afterward, as the projected body draws nearer and nearer, will incline its mercury end more and more toward that body and its benzol end correspondingly toward the distant stationary one? And when, finally, the moving body comes close up, while the other continues still as distant as ever, don't you know, as well as you can reason yourself to any knowledge, that *the tube will stand altogether erect,* as did the soldered cubes?

But our picture is not yet complete, for if we do not speedily find some way to *support the tube* against the major attraction, there will presently be a collision and the contents of our vessel will be ingloriously spilled. For this sustaining purpose, let us invoke the vortical suction of the Prime Resultant, and, incidentally, let the sun's powerful attraction supply the place of the proximate body. Then we shall have the odd spectacle of a great long rod circling the sun—veritably a visualized vector. Alas for our oddly constructed planet! In nearing perihelion, the sun's heat has proved too much for it; the mercury, indeed, has weathered the test, but the water and benzol have evaporated and, expanding, burst the tube and behold—a *comet*!

In the next chapter I shall explain how the real comets are formed by the explosion of neighboring stars spraying their molten materials in all directions, some of them toward us. One such big spray, being hurled with great force, quickly finds itself in a region of intense cold, where its globules soon congeal, sealing within their chilled exteriors all sorts of stellar gases cooled down to inaction. Continuing onward in our direction, at high velocity, the comet, once fairly caught in our systemal vortex, acquires an orbit, necessarily greatly elongated, but varying in inclination and direction of motion according to the angle at which it made its entry.

During transit from its old home to its new, a journey which consumes literally thousands of years, the comet (because its motion is one of explosive and not gravitational origin) soon finds itself so far away from strong rival attractions that it is able to make its integral attraction among its scattered parts dominantly felt, and, eventually, though its aggregate mass be slight, to consolidate them into a single ball, or perhaps into a vortical swirl, or gravitational unit, of small diameter. After entering the sphere of the sun's influence and connecting up with its predestined orbit, as it were, the comet forges on in regular course to its perihelion. Had it now nothing but its *projectile* momentum to depend upon, it would lose so much of this in "turning the corner" that it would inevitably fall in upon the sun. But, thanks to the torsional force of the quiver of rays of attraction that make up the Prime Resultant, the comet is upheld against the straining sun and whisked past his eager grasp, thwarting that Tantalus of his expected feast.

The crisis, however, has not been without its serious effects. The fierce heat from the luminary falling upon the massed particles, though perhaps not intense enough to fuse their crusts, is certainly able to raise their general temperature to a high state, thereby causing expansion of the confined gases, and so giving rise to multitudinous explosions of every degree of intensity. These phenomena, in the very nature of things, are most pronounced when a comet is very near the sun; which is unfortunate for human observation, because of the blinding contrast of the solar rays. The effects, however, are sometimes sufficiently pronounced to be seen and studied even despite this handicap, and reveal themselves in such strange phenomena as glowing nuclei, jets, envelopes, coma, and tails.

## COMETARY PHENOMENA EXPLAINED

In nearing the sun, the integral attraction of the comet becomes dwarfed in competition with the rapidly augmenting solar attraction and a new disposition of its component substances is rendered imperative. Instead of preserving its old sphericity, therefore, it tends to the *columnar* form, with its heavier elements at the base (sunward) constituting the nucleus, and its lighter elements, mounting rearward one upon the other in the order of their levity, making up the tail. Newtonians, consumed as they are with their unreasoning antipathy to the principle of equilibrium, argue that the tail ought to point toward the sun, his attraction upon it being superior to that of the nucleus; just as though the latter were something nailed to the sky and had itself no affinity, not to mention *superior* affinity, for the sun. In nature, comets exhibit tails only for a few weeks, or at most months, before and after their perihelion passage, and invariably point them *away* from the sun. Sometimes these tails are upwards of a hundred million miles in length, and in order for the tip to remain behind the nucleus, the former has been known to cover a distance of 40,000 miles in a single second!

Imagine such a comet suddenly clapped into a giant test-tube and the tube gently lowered to the sun; where would you expect to find the nucleus? Surely not in the *top* of the tube! And the lighter gases, would you look for them to precipitate to the bottom? Of course not! Conceive the tube with its contents translated back again to its old place in the heavens and the container annihilated, can you conjure up any good *gravitational* reason why the tail should now alter its poise? No! Cometary tails, far from contradicting the principle of gravitation, positively illustrate and *confirm* it, as do they likewise vindicate the universality of the natural law of equilibrium.

Yet such is the singular perversity of Newtonian philosophy, that it has actually gone to work and invented a new cosmic "force" to *counteract* gravity in order to bring about the very thing *gravitation implies!* Astronomers call this chimerical thing "light repulsion", and, to eke out its already developed shortcomings, they have tacked on to it an even more ethereal idea, which they call "electric repulsion". They tell us, with Pickwickian seriousness, that the sun's light exerts a pressure upon the infinitesimal motes of cometic matter, not only strong enough to counteract the solar gravity, but also to carry the particles outward with the velocity of light itself. Expanding this idea, they go on and picture to a wondering laity how cometary tails are shorn away in the very act of growing on, and, waxing still more eloquent, how they are carried away on the caudaliferous ether to distant bournes where, foregathering with other such ghostly moultings, they hatch out new planetary systems. Several mathematicians have gained undying fame by calculating this and that about the *size* of these motes and defining the relative intensity of light and electric pressures as contrasted with gravity, etc., etc., so that the theory may now be said to have as respectable standing among Newtonians as the old standbys of uncaused motions, irreducible momenta, and the rest.

On the occasion of its initial visit to the sun the comet is naturally charged with a greater cargo of gases than at any subsequent apparition; hence, after a few returns, it ceases to be visible to the naked eye and then becomes telescopic only, or is lost altogether to human sight. As long as the comet continues rich in occluded gases (whether the visit be its first or not) and its perihelion distance is sufficiently short, its advent is accompanied by an interesting display of celestial pyrotechnics. After playing its harlequin tricks for a gay month or two and casting its fiery confetti in the eyes of the staid old planets, it returns on its long road through the dark to its home in aphelion. As it so retires, it collects its scattered elements—its integral attraction more and more reasserting itself as the sun is left behind—until, after no long while, it rolls itself up into a ball as self-containedly as the earth herself. With each return, the aging comet becomes less flamboyant, its orbital eccentricity less pronounced, its inclination less arbitrary; in fine, *it grows domesticated and turns into an asteroid.* It is not true, however, that *all* asteroids have once been comets or, conversely, that all comets become in time asteroids; for many of the asteroids are native to our system, the same as the planets, while the comets may graduate into satellites, or, indeed, may end their careers by falling in upon the sun or one of the planets. This much, nevertheless, can be asserted without qualification, namely, that those *asteroids whose eccentricity of orbit is strongly marked* are of cometary origin.

Comets have their little brothers—called *meteors.* This is only to be expected from the very nature of the case. It would be extraordinary indeed if by the explosion of a star only one fragment, or one congeries of fragments, should reach us; rather should we expect a long train of scattered *débris,* many millions of miles in length, composed of congealed globules of all sorts of miscellaneous sizes. Thus Comet I, of 1861, has been identified with one stream of meteors, Biela's comet with another, and so on. Not only this, but there is a great deal of spectroscopic evidence that comets possess a chemical constitution strikingly similar to that of meteorites, which latter, of course, are only meteors that have managed to reach the earth. All of these objects, issuing in a fused state from the shattered hulk of their parent star, and consequently more or less finely divided, cool quickly in the frigid realms of space, and so remain until their projectile motion is suddenly arrested, or they come near the fiery furnace of the sun. When either of these events occurs, the meteor explodes because of the sudden expansion of its freshly heated gases within. The reason why only the larger meteors attain the earth in safety is because the friction of our atmosphere is insufficient, by reason of its shallowness and lack of greater density, to do more than slightly fuse their outside, as actual cases have proven. Sizable meteors that *do* explode are known as *bolides.*

## REMARKABLE COMETS

In order to appreciate the interpretive value of the principles just elucidated, the reader should compare the descriptions of past comets given in such books as Flammarion's *Popular Astronomy.* Take, for example, the great comet of 1843, which passed its perihelion within 33,000 miles (less than 1-25 of the sun's diameter) of the solar surface, at a velocity of 342 miles a second, through a hot blast capable of vaporizing steel, and in the teeth of a coronal resistance of undoubted immensity—yet came through the ordeal apparently unscathed, and without any perceptible retardation. More than this, it brandished a tail 198 million miles in length! The tail kept well behind the comet, consequently the tip of it must have swept through space at the velocity of about 40,000 miles in one second. Supposing that the tail averaged this length for as much as a single week, then, according to the hypothesis of light repulsion, the comet must have simultaneously grown and lost some 700 of these appendages!

Of Encke's comet we are told, first, that its period is diminishing, second, that it is not doing so as fast as formerly, and, third, that its head gradually contracts as it nears the sun and expands again as it recedes. Astronomers have been able to suggest only one way to explain the first two phenomena, namely, by postulating the ether as *slightly* resistent—"not enough to hurt but just enough to serve". Newton, you remember, was scrupulously particular to have it understood that the ether is *absolutely* imponderable, knowing as he did full well that even the least possible retardation of the planets would inevitably destroy the "divinely-ordained" equality of the centripetal and centrifugal forces and bring the whole system to grief. But even if we are gracious enough to wink at this modern indiscretion, or to concede the paradox of a medium by its *resistance* causing a *hastening* of the comet, as these ingenious savants declare, we cannot decently go further and admit that the *degree* of that resistance is declining in the same galloping ratio as required by the premises.

The mystery is easily cleared when it is recognized that Encke's comet is a comparatively recent intruder into the solar system; as is indicated by the fact of its having the highest eccentricity among the short-period comets. This, taken in connection with the additional fact that it is the innermost of its kind (where the vortical force is strongest), renders the disciplining process, at its present stage, especially noticeable and rapid. In short, its peculiarities of motion are owing to the gradual rounding of its orbit, the effects naturally dwindling as the process of approximation to perfect balance progresses. As for the contraction of the comet's head on approaching perihelion, this is obviously due to nothing else than the columnifying of the fused cometary nucleus by the sun's differential attraction—a phenomenon of equilibrism pure and simple.

## LATITUDE VARIATIONS

About the year 1890 astronomers began the investigation of a unique phenomenon. This consists in the circumstance that the latitudes of every place on the earth's surface vary slightly from day to day the year through, though they always return periodically to what may be termed their home parallel—much as the sun crosses and recrosses the equator. In more graphic language, the earth seems to wabble on its axis as though that were a material axle and had worn itself thin in its bearing, giving room for play. To illustrate: Let A be a point on a given parallel and B another point on the same parallel, but 180° distant in longitude; then when observation shows the latitude of A to be slightly above the parallel on which normally it belongs, the latitude of B on that same day will be found just the same distance below, and *vice versa.* To explain this phenomenon a dozen hypotheses of various sorts have been advanced, but, so far, none has attained the stage of demonstration. However, all astronomers are a unit in believing that the phenomenon can be due only to an actual shifting of the earth's axis with reference to the crust. In this view I, for one, do not concur.

Doctor S. C. Chandler, the eminent American astronomer, has ably and carefully analyzed the observational data and found that this movement of the pole can be expressed by a formula containing two terms, one of which varies between 85-1000 and 185-1000 of a second of arc, covering a period of about 430 days, and the other between 115-1000 and 155-1000 sec., whose fluctuating cycle is one year. These displacements, in terms of feet, are respectively between 9 and 20, and 12 and 15 (a second of arc of the earth's surface being almost precisely 100 feet) and they exhibit themselves in the form of minute rotations of the pole, produced, like the precessional circle, contra-clockwise.

In another place I have sought to emphasize the circumstance that since Newton's day many fundamental scientific truths have come to light for which he made no anticipatory provision. Here is a case in point. Had he known of the existence of this phenomenon, in addition to all the other wonderful facts astronomy has unearthed since his time, it might have occurred to him to consider, at least provisionally, whether the torsions of the sun and moon upon the earth's equatorial ring could not better apply to this problem than to that of precession, for which he did employ them. He might then have raised in his mind the reflection that CYCLICAL CAUSES should produce CYCLICAL EFFECTS, and discarded, before he had gone too far, the absurd hypothesis that the annual attraction of the sun on the earth's ring produces a diminutive arc of a big circle, rather than the diminutive complete circle it should naturally produce. In the new problem there is pressing need of the very causes Newton thus preëmpted for precession, but no astronomer dares to broach such a thing as the diversion of them to this new use, because the greater problem of precession would then be revived and make necessary a complete reconstruction and readjustment of the whole theory of the science—for which drastic course the powers that control are not yet ready.

So, instead of adopting the true reasons to explain the phenomenon in question, be the consequences what they may, astronomers are groping about for some plausible subterfuge that may serve to allay their troubled spirits and strengthen their faith in what they must know, deep down in their hearts, is not a science at all, but a *pseudo* science almost as visionary as astrology itself. I am speaking now of theoretical astronomy, remember, not of practical astronomy; for of the latter I have no words but of praise. We have just seen how, in the case of cometary tails, astronomers have invented light repulsion to take the place of the principle of equilibrium, which they wrongfully discarded, and we may now expect them to settle upon some equally grotesque theory to account for the present phenomenon so as not to disturb Newton's irrational explanation of precession. Lord Kelvin, Newcomb, and others have sought to explain the mystery on the basis of Newton's tidal theory by first deducing the coefficient of the earth's elasticity and employing this as a new basis on which to found further deductions. Others try to connect the anomaly up with continental risings and sinkings, with earthquake cycles, with atmospheric shiftings, with the alternating deposition and melting of snow and ice, and whatnot.

Paradoxical as it may sound to the ears of astronomers, it is NOT TRUE that the earth's axis shifts within her crust; nor is it true, as they imagine, that the cycles described are basically due to long-period gyrations. On the contrary, the phenomenon is produced by *diurnal* oscillations of the planet as a whole and the annual and 430-day periods are simply *periodical changes in the amplitudes* of those diurnal movements. An illustration may help to make the matter clearer: You remember how, in Foucault's celebrated pendulum experiment (by which he proved the rotation of the earth), the tip of the pendulum was made, at the end of each swing, to cut into a little circular ridge of sand. At the close of the experiment the pendulum tip left its tiny dents all round the circle as the *only record of the oscillations,* so that a stranger happening upon the scene after the pendulum had been removed might easily have supposed that the marks were caused by a toothed wheel rolled round the ridge, or in any way, indeed, save the right one.

Now, astronomical observations, especially in cases of such super-delicacy as required in this case, cannot be made at any hour of the day or night, but only at the most propitious time of all—*midnight.* That is to say, the marks or "indentations" are registered twenty-four hours apart—just as Foucault's pendulum's dents were spaced by a *second* or so. A record being kept of these latitude observations would speak only for themselves, but would give no hint as to what occured *between* their makings. Now, astronomers have mistakenly assumed out of hand that the condition between times is the same, or virtually the same, as at the moments when the observations are made—in other words, they see the dents in the act of being made in the circular ridge of sand, but they do not see, or allow for, the vibrations of the pendulum in between; they recognize the existence of the long-period variations, but remain blind to the even more significant diurnal ones.

We have only to suppose that the earth, besides its ordinary diurnal revolution, wabbles once around on its *true axis during each day,* and from day to day, in a rhythmical manner, with only the *lengths* of the amplitudes varying seasonally and monthly according to the changing positions of the sun and moon, to which latter we naturally turn for the dynamical explanation. Thus may we combine consistently the actuality of daily oscillations with Chandler's long periods of a year and 430 days respectively. These oscillations, be it observed, are not simple rocking motions, back and forth like a pendulum (which would not harmonize the phenomena), but a rotatory motion, which the term wabbling aptly describes. The conditions require that when A is on the meridian of midnight with a latitude *plus,* B at *its* midnight, twelve hours later, must show a latitude by the same amount *minus.* A wabble of a period of twenty-four hours, coöperating with the diurnal rotation, supplies this requirement. Were it possible to make accurate observations at all hours the same as at midnight, it would be found that both A and B shift their latitude *all day long* with a double wave-like motion, each being half the day above, and the other half below, its home parallel. This wabble varies *in radius* according to the season of the year and the position of the moon, hence the variational showings of long period.

What causes this phenomenon? is naturally the next question. I attribute it to the same causes that Newton erroneously employed to explain precession; only instead of referring the solar and lunar attractions specifically to the equatorial ring, I prefer to refer them to the more general entity of the earth's center of gravity. I am logically privileged to make use of these causes, because I have freed them by employing others to explain the phenomenon of precession.

The earth having been described already in these pages as a body seeking its lowest center of gravity with reference to the sum of the stellar attractions, it follows that that center is eccentrically located with respect to her center of figure; that is to say, the two do not coincide, but the c. g. is slightly north of the c. f. In this condition we have a repetition of the basis upon which I predicated the explanation of the moon's longitudinal libration. (See, also, Chap. XIII.) The distinction between that case and this, however, lies partly in the fact that the earth is supplied with mobile oceans, whereas the moon is solid clear through; and partly in the distances, sizes, configurations, and relative motions of the attracting bodies. The principle of purchase, or leverage, accordingly again comes into play, necessitating application of the rule of inverse cubes in passing upon the relative perturbations of the sun and moon—our old ratio of 1 to 2.25. That such a complicated combination of dynamical factors as this should produce diurnal oscillations of the earth seems to me self-evident, and I shall therefore not labor the point. Nor do I think it necessary to enlarge on the presence of the *annual* term found by Dr. Chandler's analysis. The 430-days term, however, demands elucidation:

Were the sun and moon always in alignment with the earth, and did they not move from their places, the sidereal day would be the same as the solar day and the "lunar day" (if we may permit ourselves this last expression for the sake of simplicity). In that case, there would be no fluctuation of latitude at all. But the moon is *not* stationary; she steadily gains over the imaginary position we have just pictured her in, a position, however, which is monthly realized when she is said to be new. Now, the time elapsing between new moon and new moon is known as the synodical month, and its length is 29.53059 days, whereas the sidereal month is only 27.32166 days, consequently the latter in one year gains on the first 2.20893 times as many days as 27.32166 days is contained times in 365¼ days. Performing the operations, we obtain 29.5 days, which, because the moon's torsional effect is 2.25 times as great as the sun's, must now be multiplied accordingly, yielding 66.4 days. Adding this to the annual period, we have 431.6 days, which is a very close approximation to Dr. Chandler's second term, considering the many uncertainties and difficulties involved.

A very interesting, not to say significant, coincidence brought out by this avenue of investigation deserves to be mentioned. If we average Dr. Chandler's four fractions (125-1000 sec.) and the two periods (398) days, and multiply them together—this on my hypothesis that the variation is of *diurnal* causation—we obtain 49″.75, a quantity startlingly near the 50″ .2 arc annually added to the precessional circle!

# VII

# THE NEBULAR HYPOTHESIS

WHAT militated most against the earlier acceptance of Newton's doctrine of the universality of gravitation was the unreadiness of his generation, accustomed though it was to the acceptance of ideas on faith, to believe that the force of gravity, any more than any other force of which they knew, could act across a void. It took the world of science half a century to assimilate this generalization, familiar though it may now seem to us. Unfortunately, the very fact that, in spite of its initial season of incredibility, it nevertheless won acceptance in the end, became a powerful lever in support of wild hypotheses whose only merit lay in their novelty. Since then, a premium seems to be placed on extravagance in invention, regardless of the element of probability or plausibility, and the only rule that appears to be recognized is, that inherited prejudices shall not be antagonized or impugned. All comers are welcome who will lend a hand at shoring up or patching up the superstructure of theory, but woe to such as I who would raze the crazy structure, in whole or in part, with intent to broaden and strengthen the *foundations*. In this chapter and the next my purpose is to give the reader as clear an idea as possible of the various cosmogonical theories that the hierarchy of science recognizes as orthodoxically sound and eligible, and then to criticize them from a practical, rather than a technical, standpoint.

The most famous name in the annals of astronomy since Newton is that of Pierre Simon, Marquis de Laplace (1749-1827). The greatest debt we owe him, in my estimation, is not his so-called Nebular Hypothesis, not his mathematical contributions to astronomical science, but his specific and authoritative confession that *Newton's system is deplorably and fundamentally deficient.* I feel sure that the laity of the present day labor under the impression that the foundation provided by Newton was sufficiently broad and substantial to support the entire superstructure of the science for all time, but such is very far from being the case, as professional astronomers well know. In fact, it is astonishing how little Newton really did explain, when we come to compare his actual achievement with what still remained to be accomplished; verily was he right when he said, "I know not what the world will think of my labors, but to myself it seems that I have been but a child playing on the seashore; now finding some pebble rather more polished and now some shell more agreeably variegated than another, while the immense ocean of truth extended itself unexplored before me." Here are a *few* of the many things he did *not* explain:

The origin of the earth's rotation on its axis, and the reason for its continuance.

The origin of the earth's "rectilinear motion", and the cause of its continuance.

The origin of the axial rotations and orbital motions of the other planets, and the moon.

The origin of the sun's axial rotation and equatorial acceleration.

The genesis of the sun and of the planets.

Why the moon does not fall in upon the earth, or the earth and planets upon the sun.

Why the orbits of all the planets are nearly circular.

Why the planets rotate on their axes in the same direction.

Why they all revolve around the sun, in the same direction.

Why they revolve so nearly in the same plane.

What comets are.

Why these revolve in elongated orbits so dissimilar from planetary orbits.

Whether the sun moves in space, and why, and how.

What effect the stellar attractions exert upon the solar system, internally and externally.

The source of the sun's heat.

The nature of the stars and their mutual relations.

The cause of the moon's secular acceleration.

The origin of the earth's equatorial ring and her continental configurations.

It was to supply some of the deficiencies above enumerated that Laplace invented his celebrated Nebular Hypothesis, which he first announced in 1796, and twelve years afterwards republished, with certain corrections and additions. In brief, his scheme was this:

The solar system originally existed in the form of a gaseous nebula that extended out from the center of the sun (which he regarded as stationary) to somewhat beyond the orbit of the outermost planet (at the time of his death Neptune was yet undiscovered). This nebula had an *inherent* motion of rotation around an axis at right angles to its plane and passing through the center of the sun. At first the nebula was probably spheroidal in shape, but by virtue of its axial rotation it was gradually flattened out into a discal form. In the course of time the rotary motion, by reason of the contraction of the mass, became accelerated, so that finally the nebula spun around so swiftly that it cast off an outside ring. Relieved of the weight, the residuum revolved all the faster, and a second ring was cast off. This process continued then until as many rings had been thus shed as there are planets, and there finally remained only the central residual mass which now constitutes our sun. This latter, being eternally hot and bright, naturally suggested to Laplace that the nebula was incandescent to begin with and retained its temperature throughout the process, an inference all the more plausible because the interior of the earth, also, is known to possess a high temperature.

The several rings thus thrown off (or abandoned, as some insist) in good time gathered into balls of nebulous matter possessing axial rotations, like the parent nebula, and, following precedent, likewise exchanged the spheroidal for the discal shape and eventually flung off smaller rings, which later developed into satellites.

Granting the premises, then, Laplace, up to this stage, had *ostensibly* accounted for these things: first, the revolution of the planets in the same direction; second, their revolution in (about) the same plane; third, the near-circularity of their orbits, and, fourth, the solar heat.

He had still, however, to account for the fact that all the planets rotate, like the earth, on their axes, and in the same direction in which they orbitally revolve. To do this, he gratuitously assumed that the nebula revolved in hydrostatic equilibrium, that is to say, *like a rigid solid.* His reason for so doing was this: the planets roll on the perimeters of their orbits like wagon wheels along a cartway, that is to say, their *distal* halves (as viewed from the sun) move *forward* while their *inner* halves move relatively *backward.* It was essential, therefore, for the sake of mechanical consistency, to depict the *outer* edge of the cast-off ring as traveling *faster* than the *inner* edge, just as the circumference of a flywheel travels at a faster rate than the inside of its rim.

As the data stood during Laplace's life, the Hypothesis correlated them all quite faithfully, a circumstance which doubtless accounts for the amazing hold it so long retained upon the scientific mind. The first notable departure from it came in the fifth decade of the past century, when heat was identified as a mode of motion. However, this departure was more in the nature of a development or vindication than a contradiction, inasmuch as it relieved the theorists from defending the absurdity of the nebula's maintaining its temperature in the face of the cold of space. But the day of disaster irretrievable was on its way. In 1877, Prof. Asaph Hall, of Washington, discovered the two moons of the planet Mars, Deimos and Phobos, neither one of them more than seven miles in diameter, and incidentally ascertained that the latter (and inner) of these revolves around its primary more than three times as rapidly as the planet rotates on its own axis. Some five years later, Keeler proved, spectroscopically, what Clerk Maxwell had previously shown deductively, that the rings of Saturn are neither liquid or solid, as theretofore supposed, but consist of multitudes of minute satellites, and that the inner ones revolve faster than the planet rotates on its axis. These two incompatible facts, added to the more recent discoveries of the so-called retrograde motions of three or four of the satellites, and taken in connection with its violation of the doctrine of conservation of moment of moments, have virtually given the Hypothesis its quietus.

## CRITICISM OF THE NEBULAR HYPOTHESIS

You may ask, of what use is further criticism of Laplace's Hypothesis if the death blow has already been administered? My answer is, that science has not yet sufficiently learned the lessons the career and final fate of the Hypothesis are capable of teaching. The truth is, it should never have *required* killing; it was too fatuously and inherently absurd on its face to have merited more than passing consideration. Of what use is it to postulate the *axiomatically impossible* and then to ring the changes on it for a century, only to learn in the end, by painful experience, what was but too glaringly patent at the outset? I give everybody out of Bedlam credit for knowing, *a priori,* that a gaseous nebula six billion miles across, far thinner than atmospheric air, could by no possibility, whether in the past, the present, or the future, rotate like a solid, spontaneously and without motive power, for thousands of years on end! If our intelligence cannot teach us obvious things like this, it can teach us nothing, and we may as well give up all efforts at learning. Should scientists have *needed* to await the discovery of Phobos in order to learn from that midget so rudimentary a lesson? But let us expose to ourselves the full extent of our recent folly in the hope of deriving wisdom not to go on perpetrating similar lunacies in the future.

To begin with, what think you was the degree of density of the postulated nebula? This is easy of calculation. Spheres being to each other as their cubes, and Neptune's distance from the sun being 6400 times the solar radius, it follows, that when the nebula filled the Neptunian orbit, every *cubic inch* of the sun's substance was dispersed in a cubical space 533 *feet* each way, that is to say, a space whose six sides are each equal to a large-sized city block! Imagine a great air-tght box of this magnitude, filled with air of sea-level density, and then imagine this air pumped out and condensed into liquid form; it would fill a hall sixty feet each way. Reserve but *two tablespoonfuls* of this liquid (pouring all the rest away) and heat the same as hot as your imagination can picture, and then inject it back again into the big exhausted space from which it was pumped, and you will have a mathematically accurate idea of the nature of the Laplacian nebula! Physicists inform us that, despite their utmost care and ingenuity, they are unable to produce artificial vacua within 1-1000 part as rare as this; Let fall from your eyes, I pray, the glasses of prejudice and look, and, looking, do some sane and sincere thinking. Do you, in your inmost soul, believe that such a hyper-vacuum could *and actually did rotate on its axis* LIKE A RIGID SOLID and, so rotating, fling off great rings by centrifugal force? Have you in all your reading come upon a fairy story, a superstition, a dream, an hallucination so utterly abandoned and nonsensical as this? Yet, for nearly a century has this absurdity been taught by a science that prides itself upon being the only "exact" one outside of mathematics! If this be astronomy, then let astrology be hailed as true gospel.

Let us now inquire what is the extent of the sun's attraction at the distance of Neptune, in order to ascertain the degree of "hydrostatic pressure" brought to bear on the material of Neptune's ethereal ring. Not to weary the reader with too much detail, let me give a few calculated results. The attraction of the sun on a given particle as distant from him as Neptune is about one fourteen-hundred-thousandth as great as that of our earth on a like particle at her surface. It is only about one-fourth as great as that of the moon upon the ring on your finger, and is proportionally about equivalent to that of the attraction of your own body upon the clock resting on the mantel a few feet from you.

Now, gravitational attraction is one thing, but *tangential torsion* by it is altogether another. It is quite admissible to conceive of the particles of which we are speaking as being held back by their gravitational attraction from escaping into outer space; but it demands the maximum of credulity, scientific or otherwise, to believe that the *friction* between particles so sparse and minute as here demonstrated, and cohering only by grace of a vivid fancy, could ever, under any circumstances, sustain a general torsional motion. To refer again to our illustration, this friction is relatively the same as the act of turning around on your heels (while still preserving the intervening distance) would have on the clock, not to draw it toward you, remember, but to *rub* it to one side—no, even less, because the air intervening between the clock and you is many thousands of times denser than the postulated nebula, and a proportionately stronger frictional medium.

Again, Laplace made no attempt to explain how his unique nebula came into existence—he merely *postulated* it. According to modern molecular theories, be they true or false, the molecules are perpetually seeking freedom and to scatter themselves as thinly as possible through the wide reaches of space. Yet here we have our doctrinaires soberly telling us, that not only did the Laplacian molecules, without any particular reason, congregate into a vast heap, but that they cohered to each other with a tenacity *many thousands of times more firm and rigid than the staunchest steel!* Moreover, after the rings severally parted, why did they not *continue* in the "solid" state, seeing that they were then relieved from torsional strains, instead of immediately *dissolving,* and later reuniting, as Laplace described; and, once dissolved, why and how did the minor nebulous masses manage to *reacquire* the "solid" attributes in preparation for the casting off of the secondary rings? Yet not for plain, practical, common-sense reasons like these have scientists thrown off the Laplacian incubus, but for such relative trivialities as the behavior of little Phobos; that cosmic gnat upon which science foundered after banqueting upon this caravan of French-served camelopards!

In short, the Nebular Hypothesis of Laplace removed no difficulties whatsoever, but only set up futile others. In its initial statement he frankly assumed, as much as did Newton himself, a physically uncaused motion for his matter; second, he assumed its incandescence, despite its envelopment by the unspeakable cold of space; third, he postulated an unnatural cloud-form; fourth, he made no attempt to explain how the nebula originated; fifth, he took no account whatever of the fatally disturbing factor of the sun's motion through space; and, sixth, granting him all his egregious postulates, the machine he invented was geared too high to keep going, even had it ever got started. To speak frankly, the Hypothesis bore upon its face such crass imbecilities as should have condemned it *instanter*. Even had it provisionally solved all the details it was intended to do, its palpable and inherent defects should have discredited it nevertheless, and such apparent responsiveness been laid to the credit of mere coincidence. As it has turned out, science has frittered away a century in laboriously putting this grotesque wraith through a series of imaginary gymnastics, only to have it perversely turn and twist the wrong way like a double-jointed harlequin. In its application to details the Hypothesis has been found consistently disappointing.

From Laplace down to Mayer and Joule, scientists peacefully believed in the possibility of this nebula being superheated; but no sooner did the *Mechanical Theory of Heat* appear than they confessed their previously concealed misgivings and welcomed the newcomer with open arms. With a great sigh of relief they improvidently cooled with its breeze the nebula's incandescence down to the zero of space, and began to build with the chilled embers the burning sun and molten worlds. New phrases, such as "kinetic energy", "energy of position," etc., sprang up, which, interpreted, mean, that by the mere coming together of the particles of the nebula under the constraining influence of gravity, heat was produced by their mechanical impacts sufficient to melt the substance of the forming planets, and to endow the sun with a supply of caloric capable of lasting that prodigal milliards of years. Thus science rested in smug content until Helmholtz, the great physicist, fortified the theory with his idea of a slowly contracting sun, so that certain sleepers who had given some signs of waking were lulled into still deeper slumber.

Of late, however, it has begun to dawn upon scientists that their theories involve the ultimate destruction of the universe by the dissipation of all heat, when the last impact shall have sounded, and all the worlds shall finally have been gathered into a single inert mass. In the succeeding chapters I shall endeavor to disprove this dismal forecast.

In order to convey to the reader, in as concrete and graphic form as possible, the current scientific notion of how the earth's internal heat came about, as well as the heat of the sun and the major planets, let us imagine the substance of the sun divided into flakes, say a hundred to each cubic-inch of matter. It is a pet idea of modern science that the *farther apart* the particles of matter are, the greater their "energy of position"; so let us meet her views, as nearly as we know how, by picturing the nebular field divided into cubical chambers 100 feet each way, and allot to each chamber one such flake—its full share. Now, although Laplace assumed these flakes (of course he did not use this particular illustration) to be incandescent, modern science magnanimously admits they could not have been so, exposed as they were to the absolute zero of space. But, says science instead, these flakes immediately began to attract each other and to cause their mutual collision with such force as not only to keep themselves and their neighbors warm, but to store up so much *excess* heat that after several hundred millions of years the four major planets are still in a molten state, and the earth's interior so hot as to melt granite and every instant to threaten her cataclysmic disruption! Assuming that the earth was actually formed in this manner, that the process took the moderate period of five million years (which is much less than scientists ordinarily allot), and that the accretions were gradual and uniform, figures will show that the average daily sprinkle in the earth's case could not have exceeded *one-fourth of an inch!* When, in addition, we take into account that the flakes and the planet itself were continually exposed to a far colder than arctic temperature, and that the sun had his own future to look after the while, one begins to feel, does he not, that the effects of this cosmic snowstorm have been somewhat Munchausenized?

But here I may be accused of unfairness in choosing the simile of a snow-storm, as no doubt the substance of the nebula was more compact than that, say in the form of meteors. To this I answer, first, that Laplace specified *gaseous* matter, which is still lighter, and second, that, even so, the larger the particles the fewer the impacts and the farther between, hence the arithmetical aggregate would be just the same; but, fortunately, there is a second answer, which may fairly be held to be experimental in character; and in weighing it let it be remembered that the earth is now at its maximum of attractive power. I quote verbatim from Professor Percival Lowell's book, *The Evolution of Worlds* (p. 41). He says:

> Most meteorites are stones, but one or two per cent are nearly pure iron mixed with nickel. When picked up they are usually covered with a glossy thin black crust. This overcoat they have put on in coming through our air. Air-begotten, too, are the holes with which many of them are pitted. For, entering our atmosphere with their speed in space is equivalent to immersing them suddenly in a blowpipe flame of several thousand degrees Fahrenheit. Thus their surface is burnt and fused to a cinder. Yet in spite of being warm to the touch their hearts are still cosmically cold. The Dhurmsala meteorite falling into moist earth was found an hour afterwards coated with frost. Agassiz likened it to the Chinese culinary chef d'oeuvre, "fried ice". It

is the cold of space 200° or more Centigrade below zero, that they bear within, proof of their cosmic habitat.

I ask, How many such meteoritic impacts as this of Dhurmsala at *200° below zero* would be required to make up a sun as *hot* as ours? or how many million years would be required for them to *"cool" up* to the *molten* condition of the major planets?

Here is another piece of testimony from the recent work of Professor T. C. Chamberlin, of the University of Chicago, *The Origin of the Earth,* (p. 163):

> Meteorites, even after they have plunged through the whole atmosphere and into the earth, are said sometimes to retain a very low temperature within. *They are reported even to freeze the earth in which they imbed themselves.* At any rate, the low temperatures brought in from space must be set over against the heat of atmospheric friction in the ledger of temperature effects. Very significant, in this respect, is the almost incredible existence of a small class of meteorites largely formed of volatile and combustible hydrcarbons. These have reached the earth without either complete vaporization or combustion.

The shortcomings of the collisional theory became early apparent, so that, in the year 1854, Helmholtz was led to propose a new explanation of the solar heat. Discussing this theory Doctor Abbot says (*The Sun,* p. 277):

> Helmholtz pointed out that the shrinking together of the sun converts potential energy of position finally into heat. Several authors have made computations of the quantity of energy which would be available from this source. *Their results have generally been based on the assumption that the sun was originally a nebula filling a sphere whose diameter was the orbit of Neptune.* It appears that the condensation of such a nebula having the mass of the sun would have furnished thus far about 25,000,000 times as much energy as the sun now loses each year.
>
> According to Helmholtz's view, a contraction of about 250 feet per year in the sun's diameter would suffice to sustain the present solar radiation. At this rate it would require about 10,000 years to reduce the apparent diameter of the sun by one second of arc, so that, so far as telescopic observation is concerned, the contraction theory is tenable, for a change of 1/10 second in the solar diameter is unrecognizable. From calculations of Newcomb the sun will require to have shrunk to one-half its present size if it maintains its present rate or radiation for about 7,000,000 years longer.

On the same subject Doctor Young (*Genl. Astr.*, Art. 359) says:

> As to the past of the Solar history on this hypothesis (Helmholtz's), we can be a little more definite. It is only necessary to know the present amount of radiation, and the mass of the sun, to compute how long the solar fire can have been maintained at its present intensity by the processes of condensation. No conclusion of geometry is more certain than this,—that the contraction of the sun to its present size, from a diameter *even many times greater than Neptune's orbit,* would have furnished about 18,000,000 times as much heat as the sun now supplies in a year, and therefore that the sun cannot have been emitting heat at the present rate for more than 18,000,000 years, if its heat has really been generated in this manner.
>
> But this conclusion rests upon the assumption that the sun has derived its heat solely in this way, and the recent discoveries with respect to radium and radio-activity strongly suggest other causes which may have added large contributions, and may still be operative in maintaining the solar radiation.

Appropos of the same topic, we may add this from Doctor Newcomb (Art. *Sun,* Americana):

> If the sun were merely losing energy like an ordinary hot body cooling off, a very simple calculation will show that it would be so cooled off in the course of 3,000 or 4,000 years as no longer to radiate much heat. It is clear that such has not been the case. Yet the most careful study shows no possibility that it can be receiving energy from any outside source. Moreover, the geologists assure us that the stratification of the rocks, as well as many other phenomena associated with them, proves that the sun has been radiating heat to the earth at not much less than its present rate for hundreds of millions of years.

How fertile in expedients, these astronomers, and how well they love to eat their cake and have it too! Consider, if you please, these facts: Away back in 1853, when Helmholtz put forth this explanation, the Laplacian hypothesis was in its heyday, and not a voice in the land of science was there heard against it. At that time it was regarded as "one of the most well-attested facts of human knowledge". Now, if there was anything clear about that conception, it was, that absolutely the *whole* of the matter that composed the Neptunian annulus went into that planet and his satellites; so in the case of the Uranian annulus, and so in turn with all the planetary annuli down to and including Mercury's. Yet in all the estimates I have come across in my reading, I have failed to find a single one that does not construe the Helmholtzian sun as having contracted from the very *periphery of the original nebula.* What is the meaning of such crass misrepresentation? Is it due to innocent oversight, or to stupidity, or to intentional duplicity? Be the reason what it may, the truth remains that the sun cannot be consistently predicated as having collapsed upon itself from a greater distance than from the line of Mercury's orbit. Now, Mercury is only 1-80 as far from the sun's center as Neptune, and if we take the square root of 80 (to allow for gravitational variation) and divide Young's estimate by that quantity, the life of the sun becomes theoretically reduced to a paltry 2,000,000 years!

The situation is in no way improved by postulating a *meteoric* in lieu of a gaseous nebula, should such a substitution be attempted. In the contemplation of science the original nebula, however constituted, possessed a concerted movement of rotation about an axis, and there is no logical warrant for asserting that part of it took on orbital motion while the rest was free to fall. Even conceding that this last *may* have been the case, that part which was free to fall would inevitably have traversed the distance from Neptune to the sun within a few years at most, and its collisional effects been ages ago dissipated. Indeed, it was precisely to escape this galloping culmination that caused astronomers to look with so much more favor on the gaseous hypothesis. In all cosmological speculations, duration is of the essence, and particularly is this the case here. So far, then, as the Helmholtzian explanation of the solar heat is concerned, the only feasible hypothesis is that the primordial nebula was strictly gaseous and that the sun contracted to his present volume from a maximum radius no greater than thirty million miles, equivalent to a radiating longevity of less than 3,000,000 years, liberally estimated.

So much for the *quantitative* deficiency of the contraction theory, now as to its *qualitative* merits. Although all astronomers, it appears, accept the theory, there is a division of opinion among them as to whether the sun is getting hotter, as time goes on, or colder. Such an elementary disagreement as this certainly does not inspire confidence, especially when neither view accords with the phenomena demanding elucidation. The sort of sun geology prescribes is one which, though *having evidently suffered many vicissitudes,* has nevertheless managed to preserve a rather uniform average of temperature throughout geological time. That is to say, if we conceive geological history to be divided into periods of equal duration, ancient, medieval and modern, the mean temperature of the sun during each of these was virtually the same as it was in the others. A *secularly* cooling or warming sun, such as Helmholtz's hypothesis contemplates, even were it quantitatively sufficient, is therefore qualitatively unacceptable. Geologists, moreover, inform us that genial and frigid ages have alternated with fair regularity in each of these enormous periods—another essential qualification on which the Helmholtzian lamp casts no light.

Until about the year 1880 it was supposed as a matter of course that because the sun is, in theory, conceived to be shrinking on account of his cooling, his temperature must be consequently falling. It was reserved for J. Homer Lane, however, to propound the weird paradox that the more that luminary *cools* the *hotter* he gets! I quote Sir Robert Ball's exposition of the idea (*Story of the Heavens,* p. 522):

> And now for the remarkable consequence, which seems to have a very important bearing on astronomy. As the globe contracts, a part of its energy of separation is changed into heat; that heat is partly radiated away, but not so rapidly as it is produced by contraction. The consequence is, that although the globe is really losing heat and really contracting yet that its temperature is actually rising. A simple case will suffice to demonstrate this result, paradoxical as it may at first seem. Let us suppose that by contraction of the sphere it had diminished to one-half its diameter; and let us fix our attention on a cubic inch of the gaseous matter in any part of the mass. After the contraction has taken place each edge of the cube would be reduced to half

an inch and the volume would therefore be reduced to one-eighth part of its original amount. The law of gases tells us that if the temperature be unaltered the pressure varies inversely as the volume, and consequently the internal pressure in the cube would in that case be increased eightfold. As, however, in the case before us, the distance between every two particles is reduced to one-half, it will follow that the gravitation between every two particles is increased fourfold, and as the area is also reduced to one-fourth, it will follow that the pressure inside the reduced cube is increased sixteenfold; but we have already seen that with a constant temperature it only increases eightfold and hence the temperature cannot be constant, but must rise with the contraction.

What sophistries are perpetrated in the name of Science! Here we are told, in so many words, that to *warm* the sun the way to do is to *cool* it, and in order to *cool* it we must *heat* it. Let us take the statement exactly at its face value and see how it works out in practice.

The world of science is pretty well agreed, I think, that the chemical constitution of the earth and the sun is much the same, and that if there be any appreciable difference at all, the sun should possess a higher percentage of the heavier materials than the earth. Nevertheless, the sun's density—that is, his ratio of mass to volume—is very much less, being only 1.4 that of water as against the earth's 5.5, and a simple calculation will reveal that in order for the former to become as compact as our globe, he shall have to contract his diameter by 312,000 miles.

Now, *why* is he so *distended?* Surely not because of his axial rotation; for, according to accepted ideas, were centrifugalization the cause, he should possess an immense equatorial protuberance, whereas he exhibits no oblateness of figure at all. There is but one answer, namely, *it is because of his exceedingly high temperature.* But if Lane is correct in asserting that the sun's temperature is *rising,* then his volume must be *expanding* from the effects of the increasing heat, and there follows a double paradox, namely, that besides growing *hotter* because he is *cooling,* he is *expanding,* because he is *shrinking!*

On the other hand, if the Laneites are in error, it does not necessarily follow that those who claim the sun is *falling* in temperature in the process of shrinking are right. The sun may, in fact, not be shrinking at all, but simply holding his own! For let us hark back to the time when the luminary may be supposed to have possessed double his present diameter, and to have had a temperature, say, twice as high as at present. Then, according to *Stefan's law,* his radiation, area for area, must have been increased in the ratio of the *fourth power,* or sixteen times, and his surface area being concurrently multiplied by four, his total radiation must, according to figures, have been 64 times as copious then as it is to-day—obviously contrary to the biological facts. Indeed, the sun dare not even be postulated as at that time possessing the *same* temperature as now, inasmuch as he would then have been radiating *four* times as much heat, on account of his greater area;which would have meant the total destruction of all terrestrial life then extant.

That the Helmholtzian hypothesis leaves much to be desired is well recognized now, though scientists were loth to admit it *prior* to the discovery of radium in 1898, when a new hope dawned. Since then, zealous efforts have been made to discover traces of radium in the solar spectrum, but so far without success. Professor S. A. Mitchell, of Yerkes Observatory, writing in 1913 (*Pop. Astr.,* No. 206), reports thus:

> From theoretical considerations we are positively convinced that there must be radium in the sun. But to prove this is another problem. With the spectra we already have we can prove nothing more than accidental coincidences. One of the problems for the solar eclipse of August, 1914, will be to obtain the spectrum of the chromosphere on a large scale with good definition, so that we may prove what we think we know, that radium is in the sun. [The eclipse mentioned developed nothing new.]

If I interpret this quotation correctly, here is an intimation that if ever astrophysicists succeed in finding even so much as an indubitable *trace* of radium existing in the sun, the whole vexing problem of the source of the solar heat will be labeled "solved" and put away on the shelf for keeps. But the radium hypothesis can never solve this problem finally, no matter if the sun be proved to contain any desired percentage of radium, or radioactive materials. It might, indeed, dispose of the *quantitative* question, but it would still leave hanging all the aforementioned *qualitative* difficulties untouched. Professor W. B. Wright, of the Geological Survey of Ireland, summing up a luminous chapter on the theories as to the causes of ice ages (*The Quaternary Ice Age,* p. 451), says:

> It must be admitted that, among the theories that have been brought forward to account for the phenomena of the Ice Age, there is not a single one which meets the facts of the case in such a manner as to inspire confidence. An almost fatal objection to Croll's theory is the date it assigns to the end of the Ice Age, which it places some 80,000 years back. If as Doctor Geer seems to have clearly established the ice margin retreated north past Stockholm only about 9,000 years ago, this practically excludes any possibility of a connection between glaciation and changes in the eccentricity of the earth's orbit.

And listen to this from Dr. Chamberlin, the world-renowned geologist (*Origin of the Earth,* p. 4):

> But this theory of a simple decline from a fiery origin to a frigid end, from a thick blanket of warm air to a thin sheet of cold nitrogen, consonant with the current cosmogony as it was, logical under the premises postulated, pessimistically attractive in its gruesome forecast, already in possession of the stage, with a good prospect of holding it—this theory of a stupendous descensus none the less encountered some ugly facts as inquiry went on. It seemed to accord well enough with an ice age, if the ice age came only in the later stages of the earth's history, but it was ill suited to explain an ice age in the earlier geologic eras. Unfortunately for it, *there began to appear signs of ice ages far back in time, and, besides, some of these had their seats much nearer the equator and, in other respects, were even stranger than the latest great glaciation.* The evidence of these earlier and stranger glaciations was at first quite naturally received with incredulity, but the proof grew steadily stronger with every new test, and the range of the evidence was found wider and clearer as exploration advanced. While all this should have weakened, and did weaken, the fundamental concept of great warmth and a rich atmosphere in the earlier ages, while it should have roused skepticism as to the verity of the cosmogony on which it was based, and perhaps did so, still the old thermal concept and the old cosmogony continued to hamper all attempts at a radical revision of glacial theories.

# VIII

# RECENT COSMOGONIES

## THE CAPTURE THEORY

KEPLER'S second law, namely, that the radius vector of the several planets passes over equal areas in equal times, has since been generalized to include all circulating cosmic bodies, and is usually referred to as *the law of the conservation of areas,* or *the law of the conservation of moment of momentum.* It appears that through some unaccountable oversight neither Laplace or those who came after him ever thought of applying this test to the Nebular Hypothesis until the year 1861, when the French physicist, Jacques Babinet (1794-1872), contributed an article to the *Comptes Rendus,* in which he showed that the Laplacian conception grossly violated that requirement, and that when the sun was supposedly expanded to the orbit of Neptune, or to the orbits of any of the nearer planets, the rotation was much too slow to detach any of them by centrifugal force. At that time, however, such was the prestige of Laplace and his cosmogony that Babinet's work received but scant consideration, and even Babinet himself kept on teaching the same old fallacy, notwithstanding, until his dying day; much as Sir George H. Darwin did the Newtonian tidal theory, which he himself had so conclusively disproved. Tradition, it seems, can blindfold the best.

About a half century later, Doctor T. J. J. See, the world-renowed astronomer and Director of the U. S. Naval Observatory at Mare Island, California, in the course of his extensive researches came upon this long-forgotten article of Babinet's and brought it again to the attention of the scientific world. Even then it would have received no consideration, it is safe to say, either from Doctor See himself or from other professional scientists had the Hypothesis not in the meantime become discredited by the discovery of Phobos, the resolution of the Saturnian rings into discrete particles, and the revelation of the existence of retrograde motions in the system.

Adopting Babinet's criterion as final and conclusive, Dr. See reasoned that since the planets and satellites could not possibly have been flung off by the centrifugal rotation of the solar nebula, there was but one other way by which they could have become members of the sun's family, and that was by capture or, in other words, by falling inward toward the sun from a great distance. If, he argued, the *sun* could directly form out of the cosmic dust, why not the planets, satellites and comets, severally and independently? It requires but little reflection to see that to give plausibility to this scheme, if for no other reason, the original nebula would have to be expanded to vastly greater dimensions than that of Laplace, and accordingly Dr. See himself affirms, that "it was between one trillion and five trillion miles in radius."

It was not only obligatory but natural for Doctor See to seek to correlate, as part of his cosmogonical scheme, all the modern developments of the science. One of these innovations was, of course, the doctrine of light and electrical repulsion. Laplace, as you know, had taken his nebula for granted; but this, Dr. See supplies by derivation from the impalpable dust expelled from the stars "gathering into clouds in the opposite parts of the heavens." His nebula, then, differs fundamentally from that of Laplace in being of the *meteoroidal* and not the gaseous type—a very material distinction, especially in relation to the applicability of the Helmholtzian explanation of the solar heat.

Another distinction between Laplace's and See's points of view is, that whereas the former frankly postulated an *inherent* rotation of his nebula, the latter thinks to help matters by adopting a tone of doctrinal authority and finality, without deigning to offer either argument or proof. Let me here quote a paragraph or two from Dr. See's article on *Cosmogony* in the *Americana* (an article, by the way, in which he devotes fourteen pages, out of the fifteen allotted, to the exploitation of his own scheme, in entire exclusion of such rival inventions as Darwin's Tidal-Evolution theory, Chamberlin's Planetesimal hypothesis, Bickerton's Third-Body theory and Svante Arrhenius's contributions to the same subject):

> The dust carried away by repulsive forces gathers here and there into clouds, and when such a mass settles the result is a cosmical vortex, which whirls and slowly develops into a cosmical system. Thus the stars by the expulsion of fine dust form nebulæ, and the nebulæ in turn by condensation form stars and systems. The clusters, like the whirlpool nebulæ, have a tendency to spiral movement. The attendant bodies, however, are never thrown off, but captured and added on from without. The heavy bodies drift toward the centers of attraction already developed, while the fine dust alone is diffused and carried away under repulsive forces to form other nebulæ which will sometime condense into cosmical systems.
>
> The solar system was formed from a spiral nebula, revolving and slowly coiling up under mechanical conditions which were essentially free from hydrostatic pressure. And spiral nebulæ themselves arise from the meeting or mere settling of unsymmetrical streams of cosmical dust. The whole system of particles has a sensible moment of momentum about some axis, and thus it begins to whirl about a central point, and gives rise to a vortex. In the actual universe the spiral nebulæ are to be counted by the million, and it is evident that they all arise from the automatic winding up of cosmical dust, under the attraction of their mutual gravitation. The two opposite branches of the spiral nebulæ, so often shown on photographs, represent the original streams of cosmic dust which are coiling up and forming gigantic spiral systems. * * * The dust carried away (from the stars) by repulsive forces gathers here and there into clouds, and when such a mass settles the result is a cosmical vortex, which whirls and slowly develops into a cosmical system. Thus the stars by the expulsion of fine dust form nebulæ, and the nebulæ in turn, by con-

densation, form stars and systems. The clusters, like the whirlpool nebulæ, have a tendency to spiral movement.

It will be remembered with what scrupulous care Newton strove to impress upon the world the notion that cosmic space is *absolutely* clear of any ponderable medium. Why? Because he recognized, even if his successors affect ignorance of it, the absolute necessity, under his theory, that the infinitely accurate adjustments between gravity on the one hand and the tangential velocity of the circulating body on the other, ordained, as he postulated, by the Creator, dare not on any account be altered, even in the slightest, without immediately and irretrievably destroying (not merely imperiling) the whole system. Since his day, however, a few phenomena, such as the moon's acceleration and the acceleration of Encke's comet, have come to light that have put the mathematicians sadly at a loss to explain gravitationally, save on one *perilous* assumption, namely, that the ether, or some other cosmic medium mingled with it, is opposing the free passage of the revolving bodies.

It may strike the lay reader as paradoxical to be told that the *acceleration* of an orbitally revolving body can be explained by its *retardation,* but the acrobatic astronomer of to-day is equal to any emergency. His explanation is, that a body so retarded in its orbit is thereby forced to fall to a lower level, where, he tells us, under the mystical law of conservation of areas, "it is *natural* for bodies to move and revolve faster than at greater distances." Not only, says he, does the resisted body miraculously recover the velocity lost, but it actually acquires a tangential velocity *greater even than at first!* Such is "celestial" mechanics!

In addition to thus cajoling themselves into believing that retardation makes for speed, just as Lane persuaded them that the sun, by cooling, becomes all the hotter, our learned doctrinaires, proceeding along the same lines, have succeeded in convincing themselves that a concomitant effect of this process is to cause the orbit of the retarded body to become more and more *rounded.*

This myth is the chief text and stock in trade of our author, who, in spite of his affectation of originality, is quite prosaically orthodox. He conceives the planets and the satellites, whose orbits are all subcircular, to have nucleated in the borders of the nebula, on the order of a trillion miles distant from the central sun, and thence to have descended through the nebular matter, which he defines as increasing in density toward the middle. At first, he says, their orbits were very elongated, but as they severally came nearer and nearer to the sun, they encountered stiffer and stiffer resistance from the nebular matter enveloping them, causing them to fall to still lower levels, and consequently to hasten their velocity and take on greater rotundity of orbit. To quote him again:

> In the writer's recent researches on the origin of the solar system, however, it has been shown that the orbits of the embryo planets were originally hundreds and perhaps thousands of times larger than they are now, and have since been reduced in size and rounded up by the secular action of the resisting medium formerly pervading our system. As the planetary orbits were once of vast extent, and have since contracted their dimensions, it follows that the embryo planets once formed a connecting link with the present system of comets. In the course of immeasurable ages, the planetary system contracted its dimension enormously, and at the same time eat out the interior portion of the primordial solar nebula; leaving about the sun and planets a hollow shell of nebulosity, from which, under the effects of certain mutual perturbations, fragments drop down to visit us occasionally. These are the comets, and this is why they come from the shell or envelope at a great distance from the sun, an observed fact which has puzzled astronomers and mathematicians for centuries.

In explanation of the axial rotations of the planets he says:

> We may conceive that there is revolving about each planet a vortex of cosmical dust, some of which falls against the surface of the globe, and thereby accelerates its axial rotation. As the predominant motion of the vortex is forward, the planet's rotation naturally tends to become direct and the obliquity tends to disappear.

Doctor See's own appraisal of his theory can be gathered from this, his concluding paragraph:

The most remarkable fact about the capture theory of cosmical evolution is the harmony which it introduces among the most diverse phenomena. This shows that it rests on true causes and is approximately an ultimate truth, which may indeed be modified by future discovery, but will never be radically changed. It gives us a simple and natural conception of the processes by which cosmical systems are formed and unites and harmonizes all the known phenomena of the sidereal universe, so that, with the exception of universal gravitation, it is believed to embody the most ultimate law of the starry heavens.

### *The Capture Theory Criticized*

Before proceeding to the more technical criticism of Doctor See's theory it may be well enough to get a clear idea of the nature of this so-called nebula with which he is conjuring. In considering Laplace's nebula, we found its density to be that of a cubical void 535 feet each way charged with the equivalent of but a single cubic inch of liquid air. Let us compare that density with the density of Doctor See's nebula. Taking the *minimum* radius mentioned by him, namely, a trillion miles, and dividing by the radius of Neptune's orbit, 2,800,000,000, gives the number 350, which being cubed reveals that See's nebula is, in round numbers, 43,000,000 times as rare as Laplace's! We can get a more concrete idea of its extreme tenuity by multiplying the side 535 feet by 350 and erecting about this distance, as one edge, a larger cube, 35 miles each way. Such a cube would cover with its base the entire area of the State of Rhode Island, land and water. The *air* from such a cube, supposing it throughout of the density at sea level, if reduced to liquid form, would fill a cubical vat four miles each way (64 cubic miles). Discard this *all,* retaining but a single cubic inch of it, as in our former illustration, and restore it to the great void of 42,875 cubic miles out of which it came, and you acquire a mathematically accurate idea of the sort of nebula Doctor See is dogmatizing about. However, one distinction it is important to note, namely, that in place of using the substance air, which is a gas, we should substitute, say, a heaping teaspoonful of fine flour. Such, then, is the, by courtesy, "density" of the so-called "resisting medium'' which Doctor See so trustfully adopts as the corner stone for his cosmogonical edifice, or shall we say, as the *barrier* on which he relies for turning back the charging planets and training them to course in rounded paths.

But the learned gentleman has been guilty of even a worse solecism; he has incautiously fallen into the same blunder for which he blames Laplace and precisely the same which he expressly set out to correct and redeem! When he says: ''When such a mass settles, the result is a cosmical vortex, which whirls and slowly develops into a cosmical system',, what else can he have in mind than that the planets derive their orbital revolutions *from being component parts of the nebula* and gyrating *integrally* with it? Such being the case, it becomes a physical and logical impossibility for the planet to ''encounter resistance'' from the materials of the nebula itself, quite as much so as that one cannot overrun his own shadow.

In order to encounter such resistance, the planet would have to *differentiate its velocity from that of the nebulous matter* (that is, the resisting medium itself), a proceeding which would involve asserting, first, that the planet had a velocity independent of the nebula, thus reopening the whole question as to the origin of its motion; or, second, that the planet was traveling beyond the speed-limit prescribed by the law of areal motion; or, third, that the planet was accelerated by some unknown additional force, or, fourth, that, the medium was lagging and itself transgressing the law of conservation of areas. In fine, Doctor See virtually tells us four contradictory things, all in a single breath, namely: (1) That the planets are (under the areal law) gyrating *pari passu* with the nebular element; (2) that they are *outrunning* it and so incurring resistance from it; (3) that, by reason of this resistance, they are thereby *retarded* and forced to lag in the rear, and (4) that, by reason of being so retarded, they drop to lower levels where they mystically acquire fresh *acceleration!* If all these things are indeed true, and true all at the same time in Doctor See's consciousness, then must he himself be the paragon he speaks of when he says: "Not only must the astronomer be the wisest and intellectually the most penetrating of men, but in order to be a discoverer of the first order, he must be just in his habits of mind and wholly devoted to truth."

Proceeding along paths of the same order of "penetrative" reasoning, Doctor See "solves" nearly every imaginable enigma that has baffled astronomers in the past; but I shall not pursue the ungrateful task of criticising his weird speculations further than to cite a single sample of his art of deductive reasoning from his chosen premises:

> The extreme roundness of the orbit of Neptune is a clear indication that this planet moved for a long time against a vast amount of nebulous resistance. Therefore, it is very improbable that our planetary system terminates with Neptune. In all probability there are several more planets beyond the present boundary of the system, some of which may yet be discovered.

It so happens that Mercury, the innermost planet, which ostensibly has had many thousands of times more schooling at the hands of this alleged resisting medium than did Neptune, is by far the most eccentric of any, whereas, next to Venus, Neptune's orbit is the most rounded. In fact, there is no element of our planetary orbits more irreducible to a regular rule than just this one of ellipticity, as you may see from a list of the planets arranged in the order of this peculiarity: Mercury, Mars, Saturn, Jupiter, Uranus, Earth, Neptune, Venus. Furthermore, we cannot decently concede that it is in any sense consistent with See's general hypothesis that Neptune, in particular, could ever have enjoyed the benefit of the resistance of any matter now incorporated in the sun and interior planets, for all of *that* matter must inevitably have preceded and beaten him in the race of centralization. Making allowance for this factor, it can easily be figured that the nebular density of the zone actually traversed by Neptune was a *billion times less than the vacuousness already computed,* yielding a result comparable to that of a single cubic foot of atmospheric air to the volume of our earth! And it is from this *nothingness* revolving, *mirabile dictu,* in the *same direction,* and *at equal speed,* with the planet, that Doctor See predicates a "vast amount of nebul*ous* resistance!" And, finally, because he sub-consciously sees the preposterousness of his pretensions, he strategically diverts attention to an already general divination that other planets may one day be discovered beyond Neptune, as if laying in advance the foundation for a future claim to prophecy and corroboration should the *expected* come true.

### THE TIDAL-EVOLUTION THEORY

It was in the year 1755 that Kant published his work on *The History of Nature and Theory of the Heavens,* in which he maintained that, because of tidal friction, the earth's axial rotation is slowing up and our day consequently lengthening. His argument was, of course, based on Newton's theory of tidal formation, and, granting the correctness of that, Kant was undoubtedly right. He was one of the very few who have had an inkling of the truth that celestial mechanics is essentially the same prosaic thing as everyday terrestrial mechanics and not the poetic-license monstrosity that Newtonianism and Laplacianism have pictured it. He looked upon the earth *genuinely* as a physical object capable of being stopped or retarded like any other, given the natural forces; although it must be confessed he seems to have found nothing amiss in the silly notion that the earth perennially centrifugalizes her equatorial waters without the consumption of power. Though straining on the gnat, he experienced no difficulty in negotiating the camel.

Remarkable as it may seem to the uninitiated, astronomers have found a way to test Kant's conclusion. This they have done by comparing the records of ancient eclipses as far back as the 8th century B. C., almost three milleniums. The result, however, has been negative, demonstrating, according to Young (*Genl. Astr.,* p. 105):

> At present it can only be said that the change, if any has occurred since astronomy became accurate, has been too small to be detected. The day is certainly not longer or shorter by 1-100 of a second than in the days of Ptolemy, and probably has not changed by 1-1000 of a second.

In recent years Sir George H. Darwin (1845-1913), more than any other single investigator perhaps, has made a special and practical study of the tides; and, like the rest of mankind, he fell naturally into the habit of viewing the universe through the spectacles of his specialty. There were three peculiarities about our earth-moon system that struck him as possibly susceptible of correlation under the tidal principle, and to the pursuit of this object he devoted many years of his studious life. These three peculiarities, according to his interpretation, were the following:

1. The moon constantly turns the same side toward us.

2. Her surface is obviously volcanic.

3. The earth is the only planet having a single satellite, and this satellite is the largest, relatively to its primary, in the whole solar system.

Between Darwin *pére* and Darwin *fils* there lay an antipodal distinction. The former was a pioneer in the true sense, caring little for established opinions, but everything for the realities of Nature. The latter, on the contrary, gave the lie to Nature and servilely followed on the heels of Tradition. What chance, think you, has the cause of progress, when one such as he, having uttered the statement: "The equilibrium theory of tides is nearly as much wrong as possible in respect to the time of high water. In fact in many places it is nearly low water at the time the equilibrium theory predicts high water. It would seem then as if the tidal action of the moon was actually to repel the water instead of attracting it, and we are driven to ask whether this result can possibly be consistent with the theory of universal gravitation"—yet deliberately flew in the face of the truth and rushed on in the same old rut?

So Darwin, following perversely in the footsteps of the mistaken Newton and Kant, pursued the following train of hyper-speculative reasoning:

Since, according to Kant, the day is longer (or at least theoretically *ought* to be longer) than it was a millenium ago, there was probably a time millions of years ago when the earth rotated on her axis much more swiftly than she does now. Granting this supposition, there is no reason why we may not suppose, further, that she even rotated in from three to four hours; at least there is no one in a position to disprove it. However, this supposition is orthodoxically permissible; for, according to Laplace, the earth-moon system was originally a spheroidal nebula rotating on its axis, and, by common acceptation, it rotated faster and faster in the course of its shrinking. Suppose, then, that when the nebular earth had shrunk to a girth not much larger than it has at present, it had already formed a weak crust and, incidentally, was rotating in the brief period mentioned. In that case it is possible that the earth may have flung off the moon with sufficient violence to detach her permanently from the planet and make a satellite of her. It is not necessary to stipulate just how far away the moon was thus hurled, but for the sake of illustration we may suppose she was flung to a height of some 4,000 miles, and we may further assume that both parent and offspring were in the molten, or a quasi-molten, state. Under these circumstances the two bodies would doubtless raise great tides upon each other's surfaces and these protuberances would, by their eccentric attractions upon each other, retard the rotational velocities of their respective globes. This would bring into play the mysterious law of conservation of moment of momentum, and the moon would consequently go out further and further by way of compensating for her slowly expiring axial rotating energy, until, finally, that rotation would become reduced to a minimum and the satellite would turn the same face constantly earthward—as it does now.

Careful computations have demonstrated that on account of the relatively small mass of the moon, her temperature under the impact theory could not have exceeded, at the very beginning, more than 0° Farenheit. This finding is plainly incompatible with the observed volcanic rugosity of her surface. It is also to be noted that whereas, in the order of size, we have the earth, Mars, and moon, their order of roughness is, moon, the earth, Mars. By deriving the moon from the *earth*, then, we may theoretically endow the former with the same temperature as our 80-times more massive planet. When, now, we take into consideration the fact that the lunar gravity is only about 1-6 of the terrestrial, it is easy to see why the explosive effects on the satellite have been so much more telling than upon *either* Mars or the earth.

Inasmuch as the nebular earth did not give birth to the moon as early in the process of condensation as did the other planets to their satellites, but reserved its energies until it had attained a very compact stage and, under the law of moments, a commensurately high velocity, it was only to be expected that the child should prove the Titan it did.

### *Criticism of the Tidal-Evolution Theory*

Any theory that breeds enigmas faster than it dispels them is *ipso facto* false and worthless. Having explained, as he imagined, the moon's present posture by a series of assumptions on assumptions, Darwin should have gone further and proved all those assumptions. In this long series, not one of his assumptions is universally conceded by the astronomical profession—the Laplacian hypothesis is obsolescent, if not actually obsolete; the lunar volcanic theory is contradicted by a large and growing faction who insist that the lunar asperities are due to meteoric impacts; the Planetesimalists assert that the internal heat of the planets is of later genesis than the original ingathering of the nebulous matter; and so on. In any event, it is quite as sensible and scientific to accept the moon's fixed attitude as an ultimate fact of nature, as to swallow a dozen other even greater uncertainties and incomprehensibilities along with it in the effort to appear wise. But let me show you the physical absurdity of this tidal-evolution theory by a simple calculation which anyone can follow and verify:

The mass of the earth is estimated to be about 6,000,000 quadrillions of tons, hence that of the moon, which is about 1-81 as large, is, in round numbers, 74,000 quadrillions. The question is, how thick would have to be a cable of steel, of the tensile strength of 40 tons to the square inch, in order to equal the gravitational attraction between the earth and the moon *when the latter was supposedly at the earth's surface,* as it must have been in order that it may have been flung off as Darwin describes. Dividing, first, by 40 gives us 1,850 quadrillions of square-inches as the area of the cross-section of the cable. Now, the formula for the area of a circle being $\pi r^2$, performing the operation gives us the *thickness* of the cable, in round numbers, as 24,000 miles! That is to say, Darwin and all who agree with him (which is to say, all the scientific world, with very few exceptions) gravely assert that by reason of her slow contraction due to *cooling* the earth acquired so much increased axial velocity as to enable her to sunder a steel cable *more than thrice her own diameter!* Did I say *sunder?* That is the wrong word, for the bond of gravitation may be strained, indeed, but not broken. When the moon was hurled, as alleged, to the distance of 4,000 miles from the earth and became a satellite, their mutual attraction was thereby by no means destroyed, but only reduced to 1-4 of what it was before, equaling still the strength of an elastic steel cable 12,000 miles in thickness, or 1-½ times the earth's diameter. From that point on outward, Darwin assumes, by convention, that the momentum of the moon possessed at the instant of severance persists undiminished forever, sustaining her in her orbit automatically; and then he goes on to explain how the gravitational attraction of the ansae, or tidal protuberances of the moon, *lift her further and further away*—by her boot straps, as it were.

The velocity from infinity, or parabolic velocity, is that which a body falling from infinity would acquire on reaching the cosmic body under consideration. Thus, a cannon-ball falling to the earth from infinity would acquire, according to mathematicians, a velocity of 6.9 miles a second. Conversely, in order that any object expelled forcibly from the earth shall never return to it again, it must depart with this same velocity of 6.9 miles a second. Now, according to Darwin's premises, the moon must have been flung off with just that speed, *since it appears she is never to return to the earth.*

The query here suggests itself, what was the nature of the energy that accomplished this stupendous cast? It could not have been *heat,* because Darwin lays the cause of the earth's axial acceleration to its having *cooled* and shrunken. Furthermore, it can be shown that as much flinging energy would have been required as there would be heat generated by the reverse process of the fall of the moon from infinity upon the earth; that is to say, more than enough to vaporize both of these great bodies completely, Plainly, then, the energy employed was not physical, but magical or imaginary.

That Darwin was not, however, entirely devoid of the saving salt of common sense, in spite of the indications, is shown by his concluding sentence (*The Tides,* p. 284): "There is nothing to tell us whether this theory affords the true explanation of the birth of the moon, and I say that it is only a wild speculation incapable of verification." I leave it to the reader to make his own comments.

## THE THIRD-BODY THEORY

In his very interesting little book, "*The Birth of Worlds and Systems*", published in February, 1911, A. W. Bickerton, Professor of Physics and Chemistry in Canterbury College, of New Zealand, has collected together a series of papers, dating from the year 1878, setting forth a unique speculation, to which he has given the title of "*Theory of the Third Body.*" In order that I may not fail to report him correctly, I shall use his own words quite freely, omitting only inessentials. Fortunately his first chapter is itself a summary of his views:

> A pair of dead suns, that is to say two dark stars, colliding, would possess energy sufficient, if suddenly converted into heat to account for the phenomena of temporary stars. *All suns possess proper motion.* Hence it was evident that the orbits of two

suns, in approaching one another, would be similar to that of an ordinary errant comet. There would be mutual deflection and mutual distortion, and it would be extremely improbable that the suns should meet centre to centre. Much more frequently there would be partial impact or grazing collision; therefore, the problem to consider was, what would happen were a pair of dead suns to graze? * * * The portion of each body actually in the path of the other would be torn from the main portion, and these torn-off portions would coalesce into a new or third body, explosively hot and of surpassing brilliancy.

The two diminished suns would pass on, each with a fiery scar where it had been cut. Each would be set rotating, and each would be like a policeman's lantern hung by a string and set spinning. Each would present alternatively its bright and dark face to any point on its equatorial plane. * * *

Returning to the central body, which the two retreating torn suns were leaving behind between them, one saw that, at the impact, the different elements would be given a temperature that would be proportional to their atomic weight. Oxygen would be 16 times as hot as hydrogen, lead 207 times as hot as hydrogen, each and every one of these elements moving at velocities of hundreds of miles a second, yet all would be tending toward an equality of temperature, as, for example, the hot lead would be robbed of its high temperature by the cooler hydrogen. Then when something like a balance or equality was gained, the energy of unit mass of each element would tend to be inversely as its atomic weight, hydrogen having 4 times the power of escape of helium, 16 times that of oxygen, and 207 times that of lead.

Their velocities would tend to follow the law of Graham, and a kind of atom-sorting would ensue, to which the term "Molecular Selective Escape" was applied. This atom-sorting tells us that the new-born star would soon consist of a brilliant nucleus of heavy elements, surrounded with a set of ensphering shells of different gases; the lightest, hydrogen, being on the outside. * * *

The dense nucleus would be rotating, hence the outward rush would not finish with the particles coming to rest; the motion would end in a curve, and all that mass of heavy elements would form a revolving meteoric swarm, which, if the colliding bodies were small, would be a comet. If, on the other hand, it were very large, the swarm might develop into a star cluster, which in turn might become a sun surrounded with countless satellites, a nebulous star. Soon after impact the swarms might become entangled with the variable stars, and might produce the nebulosity at minimum, so characteristic of these bodies * * *. This new third body would exercise a retarding influence on the two escaping torn suns, and ought often to wed them into stars. * * *

In studying the depths of graze of colliding suns, it was found that when the graze was greater than a third of the whole mass, a kind of whirling coalescence must ensue. Such an event was thought to have given rise to our own Solar System. In this view the planets were pre-existing bodies revolving in any azimuths about one or both of the original colliding suns. These were swung into a plane by the whirl following upon the impact. The moons were pieces of cosmic dust captured by the planets when rarer than they are at present * * *.

There is a tendency for the light elements to be expelled from old systems by the high speed to atoms. These tend to congregate in positions of high potential, where matter is sparse. Agencies were found that elevated dissipating energy, and others that tended to disperse matter, until a complete mechanism disclosed itself. That rendered it possible that we exist in a cyclic scheme of creation, in which there is no evidence of a beginning or promise of an end, but a cosmic whole infinite and immortal * *.

Long ago [p. 21] both Ritter and myself, by different modes of treatment and different modes of statement of results, showed that in a complete collision of similar gaseous suns, the new sun would be only expanded to one-fourth the density; that is to say, the diameter of the new sun would be the sum of the two diameters of the two similar colliding gaseous suns. I also worked out the interesting result that all the colliding energy was exactly turned into potential energy of expansion, in this way leaving the new sun in possession of the same temperature as the old pair. Moreover, the condition was one of gaseous equilibrium and hence stable * * *.

Then [p. 96] what possibly is the right explanation (of the solar system) occurred to me, a suggestion that improves as more and more study is bestowed upon it. It is a kind of combination theory. The planets were captured by the revolving nebula, but they were independent bodies revolving in any azimuth, about one or both of the original bodies whose impact produced the revolving solar nebula. Perhaps the four inner dense planets belonged to one original body, and the four outer rarer ones belonged to the other. Further study showed that all might have belonged to only one of the original bodies. We have had much talk over it, and opinions are still divided * * *.

This, then, is the state of our idea of the origin of the Solar System, as far as we have got at present. We have not appreciably altered the idea for thirty years * * *.

### *Criticism of the Theory of the Third Body*

Given a universal affinity of cosmic bodies for each other, their collision should seemingly be the *rule* rather than the exception. Indeed, to account for their remaining aloof from each other instead of long ago accumulating in a single heap at the center of things has been one of the chief concerns of Newton and Newtonians. One way which astronomers have adopted to escape this logical difficulty is by the invention of the idea of so-called "proper motions" for stars, on the implied assumption that in the capriciousness, randomness and diversity of such motions lies the desired life-saving principle. In other words, they seek in *lawlessness* the *foil to law.* To clinch the matter, they postulate such arbitrary "inherent" motions as being likewise irreducible and self-perpetuating. A second way of escape which they have adopted is by assuming that bodies thus mutually attracted *cannot* fall to each other, but must arbitrarily rotate around their common center of gravity.

Now, we cannot allow Professor Bickerton to blow hot and cold at once; he must in duty bound stick to the precepts he ostensibly professes, or frankly disavow them. That he believes in the reality of proper motions as arbitrary entities he explicitly states, and I think we have no reason to infer aught else than that he regards these conventionally as both inherent and random. In other words, his postulated collisions are not to be construed as arising from the mating stars seeking each other out by virtue of their gravitational affinity, but purely and simply *by blind chance.* With this important consideration ever in mind, let us weigh the probabilities of such a collision coming to pass in our immediate zone of the heavens—of which alone do we know enough to speak with reasonable confidence.

The star nearest to our sun is *Alpha Centauri,* and it is 26,000,000 million miles distant; the next nearest is almost twice as far away. Now, by premiss, both *Alpha* and the sun, in the absence of the ascertained facts, might be moving haphazardly in any direction whatsoever, toward, or away, or parallel, with reference to each other. We will, however, prescribe such a movement on the part of both that shall make it *possible* for them to collide. Imagine, then, a straight line joining the two, and exactly at the middle thereof, and at right angles therewith, a circular diaphragm having a diameter exactly equal to said line of joinder. We will now stipulate, to begin with, that both *Alpha* and the sun shall possess proper motions which will cause them to impinge simultaneously on the diaphragm, but we will leave to chance just where each shall pierce it.

By thus conditioning the sun to strike within the area of the diaphragm, we have arbitrarily restricted him to a little less than one-seventh of his original liberty of movement, and so, too, with the star. By restricting *both,* however, *at the same time* we enhance the chances of collision, not by the sum, but by the *product* of these amounts whence the probability *against* our premiss is, say, fifty to one.

We will now suppose both the star and sun to possess diameters of a million miles (to make computation easy), whence it would follow that (excluding the factor of gravitation) they would be able to pass each other without touching through a square or circular opening of 4,000,000,000,000 square-miles. Obviously, the chance of either sun or star striking a *particular* spot on our diaphragm would be in the like ratio as the area of the spot bears to that of the diaphragm or as $2,000,000^2$ is to $26,000,000,000,000^2$, i. e. as 1 to 169,000,000,000,000,000,000. But not only this—the sun and star must *both* strike the *same* spot and they must do so at the *same instant* of time, consequently we are obliged to square the terms of our ratio a second time, the arithmetical result of which, for the sake of emphasis, I will write at length, at the same time multiplying it by 50 for the reasons before given. The chances, then, of the sun and this particular star, *by far the nearest of all,* meeting and colliding is only 1 in 1,428,050,000,000,000,000,000,000,000,000, and even this is an underestimate.

At this juncture it is possible that Professor Bickerton or his supporters may seek to fall back upon the aid of gravitational attraction to bring the stars into touch. To this position I offer three objections, namely; (1) It is contrary to the traditions of the science, traditions to which Mr. Bickerton, along with Newtonians in general, presumably acknowledges fealty, to the effect that unless the approaching star is *by its proper motion* headed *straight at* the sun, it cannot strike the latter, but instead must whirl round it in a conic-section orbit. (2) For the star to come fortuitously within even Neptune's distance of the sun, the chances would still be found only one in many quadrillions; altogether too remote a possibility to support Mr. Bickerton's claim to this theory being a "general order or plan of Nature." Lastly, if, in very truth, the star and sun *should* collide, *not* because of their inherent motions, but *on account of their mutual attraction,* the energy of their resulting critical velocities, directed, by Newton's second law, *toward their respective centers,* would bear to the energy of their proper-motion velocities (based on the known value of the sun's) a ratio of something like $500^2$ to $12^2$, or 1,600 to 1, thus ensuring *total* and not partial impact, thereby completely invalidating Professor Bickerton's hypothesis in its very essence.

### THE PLANETESIMAL HYPOTHESIS

There are two hinges to the cosmological shutter—astronomy and geology. In order to make it swing easily both ways, it is not only necessary that the facts of astronomy be successfully correlated with one another, and the facts of geology with one another, but *both of these sets* of facts must likewise be mutually coördinated. Nearly a score of years ago Doctor Thomas Chrowder Chamberlin, who for the past quarter-century has been dean of the scientific faculty of the University of Chicago, undertook to construct a system of cosmology from a geologist's point of view. His researches along this line have been summed up in his recent work, *The Origin of* *the Earth;* and the name which he gives his theory is, *The Planetesimal Hypothesis.*

Now, there are two fundamental astronomical conditions that especially concern geologists which must positively be supplied by any cosmological theory before it can prove acceptable, and both of these concern the sun. These conditions are; first, that a source of heat be found capable of maintaining him at practically an even *average* temperature over a period of the order of a thousand million years, and, second, that the source so found shall consistently explain the *alternation of ice- and genial ages* which have occurred in the course of the earth's geological history.

On the first of these problems Doctor Chamberlin does not, nor does he try to, throw any new light, but his chief aim is avowedly to explain the alternation of the cold and the warm periods. In the pursuit of this object, he informs us, was he led "into the cosmogonic fens and fogs," whence he emerged with this Planetesimal Hypothesis as his quarry.

Like Professor Bickerton, Doctor Chamberlin derives the solar system from the *accidental* meeting of our ancestral sun with another star; but with this difference, that whereas the former postulates actual collision, the latter contemplates only *"approach to within effective tidal range.* He pictures the sun as formerly a solitary star, moving under the head of its so-called proper motion, being fortuitously met or overtaken by just another such star as himself. Beginning by degrees to feel the effect of their mutual attraction, the pair quickly accelerated their approach, and in the natural course of events whirled once around their common center of gravity and then escaped from each other along hyperbolic paths. This incident he supposes to have occurred so long ago that the strange star has had sufficient time to lose itself among the other stars near us.

Coincidently with their thus drawing toward each other, our author conceives the visitor as having raised tides upon the sun (which may or may not have originally possessed axial rotation) and thus stimulated the eruptive tendency which observation reveals to be natural with him, and perhaps with stars generally. When the distance between them was still great, the tides, he opines, were necessarily feeble and the eruptive stimulus correspondingly faint; but later on, as the point of perihelion was neared, the tides increased to a high level and the accompanying eruptions became commensurately more terrific in their intensity, causing the sun to shoot out great bolts of viscous matter through the tidal cones located at the opposite ends of his diameter. While these bolts were thus in the act of rising, or hung suspended in space at heights ranging from zero to some three billions of miles (Neptune's orbit), they were drawn forward by the attraction of the passing star. Such matter as for any reason was deflected only *slightly* in this manner fell back to the sun on about the same spot whence it had issued; other matter being drawn forward somewhat more strongly, fell back also, but angularly, giving, as it were, a fillip to the sun, thereby starting or accelerating his axial rotation; while the great bulk of the matter was pulled forward with sufficient force to lift it into orbital paths more or less elliptical. Once given such motion, under Newtonian interpretation, they would retain it *permanently,* and in the course of time the larger nuclei, which would inevitably have resulted, would aggregate to themselves the minute particles, or "planetesimals."

Doctor Chamberlin recognizes that, in the first instance, all the orbits would probably be very elliptical, but opines that a composite of many of them ( a condition which would eventually be brought about by a multiplicity of collisions) would no doubt prove more nearly circular. Hence it is, he says, that the orbits of the planets are only slightly eccentric, whereas those of the asteroids, which have (because of their smallness) experienced only relatively few collisions, are quite capricious and, as further corroboration, he points to the fact that Mercury and Mars, the smallest among the planets, have the most eccentric orbits of all. Proceeding further, Doctor Chamberlin argues that, besides thus accounting for the circularity of the orbits of the planets, the planetesimal impacts upon the nucleating bodies probably gave rise to the direct rotations, and, furthermore, doubtless generated such retrograde rotations as are known to exist within the system.

Doctor Chamberlin seeks to explain the recurrence of ice ages in the long past, not by variations in the solar temperature, but by the periodicity of terrestrial crustal convulsions. For this he prepares the ground by denying the sufficiency of the impact hypothesis to explain any part of the earth's present internal heat, and, instead, derives this heat partly from the bodily contraction of the planet and partly from radio-activity. He argues, that during periods of quiescence this internal heat accumulates and, finally, having gained sufficient strength, forces an outlet for itself, upheaving the crust into mountain ranges and loading the atmosphere with immense quantities of carbonic dioxide. Now, carbon dioxide is an efficient absorber of heat, hence, in the periods when the atmosphere was rich with it—that is to say, during the interims between the mountain-making cataclysms—the earth experienced her genial climates. On the other hand, however, from the moment of the subsiding of these convulsive movements, the carbon dioxide began to be gradually extracted from the atmosphere, by plants to form coals and other carbonaceous deposits, and by precipitation in the rains and subsequent absorption in the rocks; a process which eventually brought about periods of low temperature immediately preceding the upheaval next in order of events. But let me quote from his own words (*Origin of the Earth*, p. 103 et seq.):

> In the sun, there is a persistent eruptive tendency of great power. At short intervals, great bolts of sun-substance are shot forth at high velocities. This takes place without any obvious outside stimulus; or, if there be such stimulus, it is not declared. Beyond question if suitable strong stimulus from without were brought to bear on the sun, such as the differential attraction of a passing star, it would respond with eruptions of much greater intensity and mass.
>
> It thus appears that from so simple a cause as the differential gravity called into action by the close approach of one massive body to another, there may arise a graded series of eruptions

ranging from fractional ejections to profound disruption and dispersion, according to the closeness of approach, the relative masses of the bodies, and their internal state. The ejected parts will pursue such courses as may be imposed on them by the new forces of attraction brought into play by the changing relations of the two bodies, both of which are necessarily in swift curving motion, while one or both are losing mass by disruptive action. * *

For an illustrative case, selected to suit our problem, let our sun, in its ancestral state, be the body approached. For its partner in action, *let a more massive star be chosen* and, for convenience, *let it be so dense and inert that its response to the reaction of the sun upon it may be neglected.* In addition it will be convenient to speak of the relative changes of position of the two as if the whole motion were made by the passing star. * * *

In selecting the closeness of approach, let us observe that only 1/745 of the sun's substance was required to form our whole planetary system. There are now known to be eight planets, twenty-six satellites, and about eight hundred planetoids; probably the whole number of the latter may ultimately be found to be a thousand or so. The average mass of these minor solar attendants is thus only about 1/745,000 of the mass of the sun. The average mass of the planets, neglecting the planetoids and satellites, is about 1/6,000. Even the largest planetary mass is less than a thousandth of the mass of the sun. It was not necessary, therefore, that the sun should give forth even so much as one-tenth of 1 per cent of its substance to form the largest planet, assuming that the whole material for the planet was ejected from the sun by a single impulse. The requirement for the earth would be about one three-thousandth of 1 per cent of the sun. It thus appears that the draft on the sun to supply the substance of the planets was very small relatively. This suggests that the passing star, if it had the mass we have chosen, must surely have had such slight stimulating effect as the case required. We assume therefore only a *quite distant approach.* * * *

Let it be assumed that the eruptivity of the sun was of the same order then as now. At present, the sun is almost daily shooting forth gas-bolts of vast dimensions and often at such velocities that they rise many thousands of kilometers above its glowing surface. Conservative computations assign these eruptive ejections velocities occasionally reaching one hundred or two hundred kilometers per second, though the average speed is less. Estimates by observers of high standing assign much higher velocities in certain cases, some of these rising to several hundred kilometers per second; indeed, velocities that surpass the sun's power of control have been announced. * * *

It is assumed that, at the time the nebula was formed, the greater eruptions of the sun were concentrated, as now, in two belts not far from the sun's equator. It is inferred that, as the star approached from a distance, its first feeble stimulus led only to moderate ejectments of sun-substance and that these suffered so slight deviations by reason of the forward pull of the star that they did not escape striking the sun's disk on their return and so carried into the sun a little momentum acquired from the star. This momentum neutralized an equivalent amount of the momentum of the sun's rotation, then opposite to its present rotation. With nearer approach of the star, the eruptions increased in mass and vigor with increased effect on the sun's rotation. With still nearer approach, a portion of the projectiles failed to strike the sun's disk on returning and swung into orbits about it. Later, a still larger part of the increasingly vigorous projectiles passed into orbits, and these orbits grew broader, but certain portions of the projectiles continued to return to the sun and affect its rotation.

During all this time the pull of the star was oblique to the normal ascensive lines of the sun's greater eruptions, and the sun and star worked at cross-purposes; but, as the star curved into the critical part of its path, where it made its closest approach, it passed directly over the belt of the sun's most effective eruptions, and not only the most favorable co-operation of sun and star were realized, but nearly the maximum mutual attraction. It is assumed that the greatest eruptive bolts were then shot forth, and that they were projected with the greatest velocity. It is taken for granted that the stimulus of vigorous action on the side toward the star would react as stimulus to eruption on the other side, and that nearly simultaneous bolts would issue from the proximate and from the distal side of the sun. It is supposed that the action would be most effective when the first eruptive belt was crossed, for then the projectile forces drew on the fullest stores of eruptive potency in the sun. The second pair of great eruptions are assigned to the stage when the second belt of solar eruptions, on the farther side of the solar equator, was crossed. These two pairs of eruptive projectiles of the first order are assumed to have been the parents of the four great planets, the two outermost—with the peculiarities of the first-born— growing later into Neptune and Uranus; the two following, favored by the pulsations set up by the previous great eruptions and by greater facilities for growth, but lacking the fullness of eruptive resources that favored the first pair, consituted the knots that grew into Saturn and Jupiter.

### *Criticism of the Planetesimal Hypothesis*

If Newton's theory of tidal production is objectively false, as Darwin, Young, Kelvin and a host of others who have made a physical investigation of the tides reluctantly report it to be, and as I think I have deductively demonstrated it to be, of course the Planetesimal hypothesis is false also, and it would seem that nothing more need be said. The tenacity of inherited opinions, however, is unfortunately often far more powerful in molding human opinion than truth itself, and so it becomes necessary to subject the theory in question to a test by the standards generally recognized, whether those standards be, in fact, genuine or spurious.

In a former place it was pointed out that, according to Newton's Corollary, the height of the tide is a function of the thickness of the equatorial ring, and that where no such ring exists there can be no tide; hence the sun could, technically, bear no tides, however favorable to their creation the physical circumstances might appear to be, for the simple reason that he has no equatorial protuberance. The learned Doctor could, indeed, reply that the *ancestral* sun might, for all that, have had such a protuberance—but then, again, it might not.

The next question to settle is as to which was the *vera causa* of this planet-creating convulsion that Doctor Chamberlin describes—was it the tidal perturbation or the internal disrupting force? The Doctor himself does not make it at all clear which is which, inasmuch as he depicts the duration and progress of the process, not in accordance with the well-known spasmodic, violent, and lawless peculiarities of explosive action, but with the smooth curve of tidal flow and ebb. Although, quantitatively, the tidal force could not have amounted to more than one-millionth of the strength of the eruptive energy requisite to project the planets, all at one time, into their respective orbits, yet he sets up the *lesser agent* as the *controller for the methodical liberation of the greater!* Granting that the tidal agitation supplied exactly the stimulus requisite to call the alleged eruptive forces into action, then the latter should have broken loose, not in the modulated manner of a tidal swell, as pictured by our author, but in a sudden and maximal outburst, from which there would follow not gradual intensification of the action, but, rather, gradual subsidence to the normal state of quiescence. In short, he makes the tail wag the dog.

Next, let us compare these two dynamical agencies quantitatively: *To project all the planets into their respective orbits would obviously demand the expenditure of precisely as much thermal (explosive) energy as would be generated by their fall thence into the sun.* It so happens that this has already been computed for us by Sir Robert Ball (*Story of the Heavens,* p. 520):

> Were Jupiter to fall into the sun enough heat would be thereby produced to scorch the whole solar system, while all the planets together would be capable of producing heat which, if properly economized, would supply the radiation of the sun for 45,000 years.

Unfortunately, Doctor Chamberlin is silent as to the magnitude of the visiting star, contenting himself with the vague statement that "it was more massive than our sun"; nor is he any more definite as to its perihelion remoteness, merely opining that it was "quite distant." It is therefore impossible for us to reduce to definite terms of thermal heat (for the sake of comparison) the tidal force that Doctor Chamberlin may have in mind. Supposing, though, that this amounted to as much as the radiation of the sun for a period of 16 days—a purposely much exaggerated estimate—it would still be only 1-1,000,000 as great as his required eruptive forces. To get an idea of this disparity, it may be correctly represented by that of a small boy in a skiff attempting to tow one of our largest battleships.

That a tidal force relatively so insignificant could, by coming fortuitously to the aid of a pent-up force so incomparably greater, not only suffice to release it, but also to master and govern its methodical disbursement and application to cosmic purposes, is manifestly absurd, unless, indeed, there be shown some automatic mechanism or some purposeful intelligence directing to that end. Supposing, on the other hand, the actuality of such an enormous explosive reservoir residing in the sun, how are we to explain either its conservation and accumulation or its multi-millenially deferred deliverance? The incessant ebullition going on in the plastic body of the sun proclaims, not a storing-up of heat but its *steady escape* and dissipation. How, in the name of sanity, can a tide, however powerful, be postulated as *liberating* gases already *freely escaping* of themselves?

It is possible that, in deference to the recent philosophical revulsion against the thermodynamic doctrine of the impermanency of nature, Doctor Chamberlin may imagine his ancestral sun as having entered upon a decline whence it was rescued and resuscitated by this tidal elixir. In that case, one might suppose the sun to have acquired a solid crust, of uncertain thickness, capable of penning up the gathering tempests within. The query then arises as to just how thick that crust should have been in order to meet the requirements of the situation.

One way to dispose of this query would be to point out that the very existence of such a crust, thick or thin, being, *by premiss*, the result of *cooling off,* precludes the hypothesizing of any such rampant interior forces at all, and that, once begun, the cooling process would necessarily continue progressively to a state of total frigidity and inaction. To assert that such a *decadent* sun harbored a thermal reserve equal to 45,000 years' solar radiation, *yet allowed its exterior to chill into an imprisoning shell,* is a contradiction in terms. Furthermore, the stauncher the shell the stronger the tide required to breach it, supposing such an event to have really occurred; and this, as we shall see, raises up new difficulties.

Whether through inability or negligently, Doctor Chamberlin discreetly refrains from citing a single concrete illustration of what relation, if any, between the star's mass and its solar distance would have sufficed to meet the demands of his problem; subtly leaving upon the mind of the uncritical reader the impression that the possible choice of combinations of these two factors is practically unlimited. Let us look into this matter closely:

In the first place, we must remember that the planets do not revolve around the sun with equal velocities, but with velocities varying greatly with their central distances. Thus Mercury, the nearest planet to the sun, travels some *eight times faster than Neptune*, the outermost. Doctor Chamberlin assumes that all the planets alike *simultaneously* acquired their tangential motions from the gravitational attraction of the passing star. If this were so, *why did they not all start out with practically the same speed?* In order to make clear how the planets acquired their *Keplerian* velocities, Doctor Chamberlin ought to show us just the spot where the strange star might have been with reference to the string of planets, just how large it might have been, and just how far from the sun, in order to bring about the present planetary scheme. Had our author succeeded in figuring out *any* such combination, he would doubtless have mentioned the fact in his book; but he doesn't. Nor shall I consume the reader's time by mathematically demonstrating the *impossibility* of any such combination existing. This much, at least, should be plain, that *inasmuch as Mercury travels faster than any other planet, the star would have to be predicated as quite close to the sun and certainly not as far away as Venus*, else the latter should possess the higher velocity; which it doesn't.

Inasmuch as only terrestrial tides have come within our daily experience, the question has never specifically arisen as to what effect, if any, the *mass of the body affected* has on the heights of its tides. For example, suppose the sun were an exact duplicate of the earth, save in the one respect of mass, and that the two were equi-distant from each other and from the moon, would the lunar tides on the sun be then exactly as high as those on the earth, or would they be directly proportional to their mass, or would they be inversely proportional, or just what rule would obtain? In the absence of any surer guide, let us assume the *tidal heights to be, inversely, functions of the masses of the bodies affected,* and that the star, in order to raise upon the sun tides commensurate with our terrestrial tides, had to exceed the size of the sun as much as the latter outweighs the earth. Supposing, then, the star to have come to within 46,000,000 miles of the sun (i. e. one-half the earth's mean distance, and one-third way between Mercury and Venus) it must, under Newton's rule of cubes, have possessed a mass some 40,000 times the solar mass and a diameter of 18,000,000 miles! It goes without saying that a body of such immensity would have swallowed up our pygmy sun in short order, nor left a vestige behind. Moving the star out farther does not mend matters; if to the earth's distance, its diameter would have to be increased to 36,000,000 miles, and if to Neptune's, more than a billion. All this calculation is based on the exaggerated supposition that a tide upon the sun comparable to that the latter produces upon the earth would have *sufficed* to pry open a crust which, until then, had been able to resist the incessant straining of a jinnee a million times stronger. That Doctor Chamberlin himself is thinking of a comparatively *weak* tide sufficiently appears from his mild expressions: "For its partner in action let a more massive star be chosen" * * * "only a quite distant approach," and "let it be so dense and inert that its response to the reaction of the sun upon it may be neglected."

In one of his veiled allusions to Professor Bickerton's theory, our author seeks to emphasize the greater probability of a "near approach" over actual collision, in which contention he is clearly justified. But, though the argument against the probabilities of his own hypothesis is thereby relatively weakened, it still remains strong enough to overthrow his, too. In order to facilitate the calculation, let us assume for the maximum field of "effective approach" a diameter of 200,000,000 miles, then the area of our original postulated diaphragm would be to it in the ratio of $200^2$ to $26,000,000^2$, or as 1 to 16,900, 000,000, which latter number being squared and then multiplied by 50, as previously explained in the discussion of Professor Bickerton's hypothesis, yields *the probabilities against even such an approach* as 14,265,500,000,000,000, 000,000, to one!

Next to the supreme problem of the origin, maintenance, and regulation of the planetary motions, comes that of the source of the solar heat. Heretofore it has been the aim of cosmologists to seek a solution of both these problems concurrently and compatibly, but Doctor Chamberlin has unique ideas of his own. Though ostensibly professing to believe in the classical division of energy into potential and kinetic, and that old stars are thermally impoverished and moribund, he naïvely makes our ancestral and presumably *senile* sun overturn the order of things and hurl the planets into their distant places. He has just reversed the film. Having started out with the avowed object of clearing up the mystery of climatic revulsions, he has ended by only floundering deeper into the bog out of which he volunteered to lead us.

### THE THEORY OF ARRHENIUS

The celebrated Director of the Physics Chemical Nobel Institute of Stockholm, Svante Arrhenius, has expounded his views on this subject of cosmology in a small volume called *Worlds in the Making.* As Doctor Chamberlin's theory was conceived from the viewpoint of a geologist, so is this one conceived from the viewpoint of the astrophysicist and chemist.

According to a recent doctrine, the molecules of matter are believed to be in constant motion. Usually these are so closely associated that they are much subject to collision, but in free space, where they seldom strike against one another, they are supposed to travel in straight lines at velocities varying with their kinds. Such motions when less than the "parabolic velocity" do not permit the escape of the given molecule, but when the contrary is the case, the molecule, it is declared, will never again return to the cosmic body from which it took its flight. Building upon this uncertain base, Arrhenius imagines these vagabond molecules to accumulate fortuitously in the dust nebulæ which, as I have previously explained, modern scientists assert to be borne out by light and electrical repulsive forces.

As the molecules of matter are fundamentally construed to be perfectly elastic, Arrhenius makes no constructive use of their high velocities, but the *dust* particles he supposes to beat each other into a glow and in this state to attach to themselves the various free molecules with which they come in contact. Thus, he says, are the comets and the nuclei of planets formed.

The orbital motions of the planets he "explains" thus (Ibid., pp. 203 and 204):

> By their collisions with the masses of gases which they encounter, they (the dust particles) gradually assume a circular movement about the axis of rotation of the nebula. In this rotation they condense portions of the gases on their surface, and hence acquire a high temperature—which they soon lose again, however, owing to the comparatively rapid radiation.
>
> Our considerations lead to the conclusion that there is rotating about the central body of the nebula an immense mass of gas, and that, outside this mass, there are other centres of condensation moving about the central body together with the masses of gas concentrated about them. Owing to the friction between the immigrated masses and the original mass of gas which circulated in the equatorial plane of the central body, all these masses will keep near the equatorial plane, which will therefore deviate little from the ecliptic. We thus obtain a proper planetary system, in which the planets are surrounded by colossal spheres of gas like the stars in the Pleiades. If now, the planets have very small mass by comparison with the central body—as in our solar system—they will be cooled at an infinitely faster rate than the sun. The gaseous masses will soon shrink, and the periods of rotation will be shortened; but for those planets, at least, which are situated near the centre, these periods will originally differ little from the rotation of the central body. The dimensions of the central body will always be very large, and the planets circulating about it will produce very strong tidal effects in its mass. Its period of rotation will be shortened, while the orbital rotation of the planets will tend to become lengthened. Thus the equilibrium is disturbed; it is re-established again, because the planet is, so to say, lifted away from the sun, as G. H. Darwin has so ingeniously shown with regard to the moon and the earth. Similar relations will prevail in the neighborhood of those planets which will thus become provided with moons. Hence we understand the peculiar fact that all the planets move almost in the same plane, the so-called ecliptic, and in approximately circular orbits; that they all move in the same direction,

and that they have the same direction of rotation in common with their moons and with the central body, the sun. It is only the outermost planets, like Uranus and Neptune, in whose cases the tidal effects were not of much consequence, that form exceptions to this rule.

Our author's second aim is to point out what he regards as Nature's method of self-restoration by reversing, as it were, the thermal hour glass and starting the heat current on the downward course once more. Quoting Clausius' old maxim, "The energy of the universe is constant; the entropy of the universe tends to a maximum", he proceeds:

> The famous Scotch physicist, Clerk Maxwell, has conceived of this case. Imagine a vessel which is divided by a partition into two halves, both charged with a gas of perfectly uniform temperature. Let the partition be provided with a number of small holes which would not allow more than one gas molecule to pass at a time. In each hole Maxwell places a small, intelligent being (one of his "demons"), which directs all the molecules which enter into the hole, and which have a greater velocity than the mean velocity of all the molecules, to the one side, and which sends to the other side all the molecules of a smaller velocity than the average. All the undesirable molecules the demon bars by means of a little flap. In this way all the molecules of a velocity greater than the average may be collected in the one compartment, and all the molecules of a lesser velocity in the other compartment. In other words, heat—for heat consists of the movements of molecules—will pass from the one constantly cooling side to the other, which is constantly raising its temperature, and which must therefore become warmer than the former.
>
> In this instance heat would therefore pass from a colder to a warmer body, and the entropy would diminish.
>
> Nature, of course, does not know any such intelligent beings. Nevertheless, similar conditions may occur in celestial bodies in the gaseous state. When the molecules of gas in the atmosphere of a celestial body have a sufficient velocity—which in the case of the earth would be 11km. (7 miles) per second—and when they travel outward into the most extreme strata, they may pass from the range of attraction out into infinite space, after the manner of a comet, which, if endowed with sufficient velocity when near the sun, must escape from the solar system. According to Dr. Johnstone Stoney, it is in this way that the moon has lost its original atmosphere. This loss of gas is certainly imperceptible in the case of our sun and of large planets like the earth. But it may play an important part in the household of the nebulæ,

where all the radiation from the hot celestial bodies is stored up, and where, owing to the enormous distances, the restraining force of gravity is exceedingly feeble. Thus the nebulæ will lose their most rapid molecules from their outer portions, and they will therefore be cooling in these outer strata. This loss of heat is compensated by the radiation from the stars. If, now, there were only nebulæ of one kind in the whole universe, those escaped molecules would finally land on some other nebula, heat equilibrium would thus be established between the different nebulæ, and the "heat-death" be realized. But we have already remarked that the nebulæ enclose many immigrated celestial bodies, which are able to condense the gases from their neighborhood, and which thereby assume a higher temperature.

The third aim of Doctor Arrhenius is to account for the sun's heat. To this end he prepares the ground by exposing the shortcomings of Helmholtz's hypothesis, as well as of others, and then selects for his own the now familiar conception of the *atomic dissociation* of matter. In this particular field he is esteemed preëminent, having won the Nobel prize in 1903 for his researches along this line. To quote again from his book (p. 91):

It is quite incorrect to assert that high temperatures must necessarily decompose all chemical compounds into their elements. The mechanical theory of heat teaches us only that at rising temperatures products are formed whose formation goes hand in hand with an absorption of heat. Thus, at a high temperature, ozone is formed from oxygen, although ozone is more complex in composition than oxygen, and by this reaction 750 calories are consumed when one gramme of oxygen is transformed into one gramme of ozone. We likewise know that in the electric arc, at a temperature of about 3000°, a compound is formed under consumption of heat by the oxygen and nitrogen of the atmosphere. A new method for the technical preparation of nitric acid from the nitrogen of the air is based upon this reaction. Again, the well-known compounds, benzene and acetylene, are formed from their elements, carbon and hydrogen, under absorption of heat. All these bodies can only be synthetized from their elementary constituents at high temperatures. We further know from experience that the higher the temperature at which a reaction takes place, the greater, in general, the amount of heat which it absorbs.

A similar law applies to the influence of pressure. When the pressure is increased, such processes will be favored as will yield products of a smaller volume. If we imagine that a mass of gas rushes down from a higher stratum of the sun into the depths of the sun's interior, as gases do in sun-spots, complex compounds will be produced by virtue of the increased pressure. This pressure must increase at an immense rate towards the interior of the sun, by about 3500 atmospheres per kilometre. The gasses which dissociate into atoms at the lower pressures and the higher temperatures of the extreme solar strata above the photosphere clouds enter into chemical combination in the depths of the spots, as we learn from spectroscopic examination. Owing to their high temperatures, these compounds absorb enormous quantities of heat in their building up, and these quantities of heat are to those which are concerned in the chemical processes of the earth in the same ratio as the temperature of the sun is to that at which the chemical reactions are proceeding on the earth. As these gases penetrate farther into the sun, temperature and pressure are still more and more increased, and there will result products more and more abounding in energy and concentration. We may, therefore, imagine the interior of the sun charged with compounds which, brought to the surface of the sun, would dissociate under an enormous evolution of heat and an enormous increase of volume. These compounds have to be regarded as the most powerful blasting agents, by comparison with which dynamite and gun-cotton would appear like toys. In confirmation of this view, we observe that gases when penetrating into the photosphere clouds are able to eject prominences at a stupendous velocity, attaining several hundred kilometres per second. This velocity surpasses that of the swiftest rifle-bullet about a thousandfold. We may hence ascribe to the explosives which are confined in the interior of the sun energies which must be a million times greater than the energy of our blasting agents. (For the energy increases with the square of the velocity.) And yet these solar blasting agents have already given up a large part of their energy during their passage from the sun's interior. It thus becomes conceivable that the solar energy—instead of holding out for 4000 years, as it would if it depended upon the combustion of a solar sphere made out of carbon—will last for something like four thousand million years. Perhaps we may further extend this period to several billions.

As his final and main thesis, the learned savant undertakes to explain how life-germs are disseminated through the universe. First, he disposes of the argument in behalf of spontaneous generation by citing its want of ocular proof and absence of physical demonstration. He then reminds us of Schwarzschild's deduction, that particles approximating .00016 mm. in diameter are the most responsive to radiation pressure, and seeks to extend this category to include plant and animal spores and germs. These, he says, being borne away, literally, on the wings of light find lodgment on distant worlds, and originate new chains of evolution more or less resembling life terrestrial.

The theories above outlined, circumscribed, strained, and mutually contradictory as they may appear, represent the supremest efforts of modern scholastic astronomy. Their very multiplicity is, of itself, in my judgment, the sufficient proof of their unsatisfactoriness and unsoundness, and demonstrates the urgent need of a cosmic philosophy big enough and broad enough to include the entire physical universe under one clear, consistent, dynamical generalization.

# IX

# THE SUN

HOW wonderful the sun!

To the casual observer our two luminaries appear to be of about the same size, but the disparity between their actual sizes is almost incredibly great. In round numbers the sun is 400 times further from us than the moon, consequently their real diameters must bear to each other the same ratio. The volumes of spheres, however, are to each other as the cubes of their diameters; hence the bulk of the larger luminary is some 64,000,000 times that of the smaller. Imagine then, the substance of the former to be divided into this number of little moons, strung together like beads upon a strand, how far do you suppose this rope of luminous orbs would reach for decking out our system? For answer, multiply 2160 miles (the lunar diameter) by 64,000,000 and compare the result, 138,000,000,000 miles, with the following dimensions, at the same time allowing liberally for artistic effects:

| | Miles |
|---|---|
| Sum of the distances from the sun to each of his several planets | 6,280,000,000 |
| Allowance for festooning | 2,000,000,000 |
| Sum of the distances from the various planets to each of the others | 43,000,000,000 |
| Allowance for festooning | 12,000,000,000 |
| Sum of all the planetary orbits | 40,000,000,000 |
| For adornment of all the subordinate systems after the same manner | 1,000,000,000 |
| Surplus for latticing the asteroids together | 33,720,000,000 |
| Total | 138,000,000,000 |

Of the intensity of the sun's brightness an idea may be gained by a comparison of the following facts: At the distance of Neptune the sun subtends an angle of slightly more than a minute of arc, or, to cite an illustration, it subtends the same angle as a cent piece does at the distance of 200 feet—obviously too small an area to be recognized as a disc. Now, it has been repeatedly estimated, with care, that we derive 600,000 times as much light from the sun as we do from the full moon; hence putting two and two together, it follows that the solar spark yields as much light to the inhabitants of Neptune as would a battery of 666 full moons such as our own.

To the novice it might seem a comparatively easy matter to determine the temperature of the sun, but that it is by no means so is shown by the great diversity in the estimates made at various periods by recognized authorities; varying, as they do, between 6,000 and upwards of a million degrees. In his recent work, *The Sun* (pp. 109-116), after describing the four methods which he deems the most dependable, Doctor Abbot says: "Hence we conclude that there is a high probability that the average temperature of the apparent photosphere exceeds 5860°, or even 6260°, on the absolute Centrigrade scale, and may be as high as 7,000° absolute Centrigrade". In passing let me record my substantial agreement in this estimate.

However, that there is still a mystery behind this one of temperature yet to be explained away, will appear from the following considerations: Construing the earth's disc as part of the surface of a sphere 186,000,000 miles in diameter (i. e., double the earth's distance from the sun), and comparing this surface with that of the sun, whose diameter is 865,000 miles, and, further remembering that the surfaces of spheres are to each other as the squares of their diameters, it develops that the radiation of each square foot of the sun's area must answer for the heating of each 46,000 square feet of the earth's area, considered as a *disc*. We should not forget, however, that the sun's rays fall on the same hemisphere only half of the 24 hours and that it *is* a hemisphere, and not a flat disc, with which we have to deal. Making corrections for these facts, we find that, instead of our former result remaining at 46,000, it must be increased to 184,000 square feet, being equivalent to a small city block 425 feet each way, or, in the farmer's standard, 4-¼ acres.

Here we must call to mind that superimposed upon this block is a great column of air, variously estimated at from 50 to 150 miles in height, but attenuating rapidly with the altitude. Not only, however, does the air decrease in density with altitude, but it decreases in temperature as well; and where the column may be supposed to end, there is no confining wall, but the doorway is left wide open, permitting the free escape of warmth into the boundless outdoors of space, where the reigning temperature is generally believed to be absolute zero, or—273° C. Inasmuch as it is impossible to make computations without definite figures to begin with, let us try to approximate the facts, as nearly as we may, by assuming that the atmospheric column in question is equivalent to another column of air of sea-level density 7 miles in height and possessed of an average temperature of 0° C. It is such a volume as this, then, 184,000 sq. ft. x 36,000 feet, that modern scientists suppose to be maintained 273°C above the absolute by the unaided radiation *from a single square foot of solar surface!* We may emphasize these figures by mentally dividing this great column into smaller proportional dimensions. Imagine a hall 100 feet in the clear covering a ground space equivalent to a small city block, then the contents will be 1-360 of our column. Again, let it be assumed that the outside temperature is 0°C and that that within the hall is maintained at 27.3° C (the main doors being all the time kept wide open) how large, think you, need the miniature sun be to serve as the furnace? The cubical contents of the hall being only 1-360 that of our atmospheric column, and the lift in temperature only 1-10 as high, there would be required a heat source possessing only 1-3600 of a square foot of surface, or 1-5 inch square, indicating a sun no larger than a buck-shot! In this estimate, be it noted, we have omitted to take into consideration the oceans, which, according to the teaching of our scientists, are maintained above freezing point solely by the sun's radiation. Were we to allow for this added achievement on the part of the real sun, the miniature one need be scarcely more than half as large as the buck-shot previously arrived at! I earnestly call upon the reader to ponder these wonders seriously in order that he may hereafter the better realize the necessity of discarding, as inadmissible, all solar hypotheses based on the doctrine of conservation of energy, and in order, also, that he may more keenly appreciate the heretofore overlooked role that the *ebullition* of the sun plays in the intensification of his radiation.

Not less amazing, when we attempt to reconcile it with the doctrine of conservation, is the reckless profligacy of Nature. All the planets taken together do not intercept more than ten times as much of the sun's radiation as the earth does, yet the latter grasps only a paltry 1-2,000,000,000 of it; the rest being uselessly dissipated in the depths of empty space, and to all appearance lost forever. What human spendthrift ever so lax and abandoned as to squander at the rate of $200,000,000 for a single dollar's worth! Nor is the sun the only celestial profligate, for the stars, one and all, vie with him in these excesses. Compare with this state of facts what Sir Robert Ball says (*Story of the Heavens,* p. 579) to the effect that were the sun composed of the best of coal, and this burned in pure oxygen, it would burn itself out in less than 6,000 years; and that passage from Doctor Newcomb, previously quoted, in which he says, that were the sun merely losing energy like an ordinary hot body cooling off, it would be so cooled off in the course of 3,000 or 4,000 years as no longer to radiate much heat!

There is every reason to believe, from spectrosopy as well as analogy, that the sun is composed of the same materials as the earth, and much in the same proportion; but, strange to relate, the former's density is *only one-fourth as great, despite the circumstance that his integral attraction is nearly thirty times greater.* By the logic of current theories he should have a diameter of less than half the size. Why, then, is he so distended? Doctor See has estimated the superincumbent pressure at a depth of one-tenth the sun's radius at 21,000,000 atmospheres, and the pressure at his center should be at least 100,000,000 atmospheres. What, then, is the physical state of his central substances?

One of the most peculiar things about the sun is the manner of his rotation on his axis. Carrington and Spoerer, noted observers of the sun showed:

1. That the sun rotates around an axis inclined about 7° to the plane of the ecliptic, and so that the axis points midway between the polar star and Vega to a position in right ascension 18 h. 44 m. and declination 64°.

2. At the solar equator the rotation occurs in about 25 days.

3. The period of one complete rotation increases on either side of the equator equally, and is about 27-½ days at 45° north or south solar latitude.

As to the high degree of the roundness of the solar disc this quotation from Doctor Abbot will show (*The Sun,* p. 26):

> Poor has lately maintained that observations indicate that the sun's equatorial and polar diameters vary relatively as much as 0.1″ during a sun-spot cycle of eleven years. According to him, the equatorial diameter is the larger at sun-spot maximum, and the polar diameter the larger at sun-spot minimum. Ambronn, however, denies that this is supported by the observations, and Moulton opposes so large a variation on theoretical grounds.

That such phenomena as sun-spots exist has been known for more than four centuries. These spots are not always visible, but come and go in cyclical periods, increasing from a state of almost complete absence for (according to Newcomb) 4.62 years and then decreasing for a further space of 6.51 years—making up a total period of 11.13 years. It must be noted, however, that 11.13 years is only the *mean* interval, the individual periods ranging between 7.3 and 17.1 years. Young has described the formation and life history of sun-spots in these words:

There is no regular process for the formation of a spot. Sometimes it is gradual, requiring days or even weeks for its full development, and sometimes a single day suffices. Generally, for some time before the appearance of the spot, there is an evident disturbance of the solar surface, manifested especially by the presence of numerous and brilliant faculae, among which, "pores" or minute black dots are scattered. These enlarge, and between them appear grayish patches, apparently caused by a dark mass lying veiled below a thin layer of luminous filaments. The veil grows gradually thinner, and vanishes, giving us at last the completed spot with its perfect penumbra. The "pores", some of them, coalesce with the principal spot, some disappear, and others constitute the attendant train. When the spot is once completely formed, it assumes usually an approximately circular form, and remains without striking change until its dissolution. As its end approaches, the surrounding photosphere seems to crowd in upon and cover and overwhelm the penumbra. Bridges of light, often many times brighter than the average of the solar surface, push across the umbra, the arrangement of the penumbra filaments becomes confused, and, as Secchi expresses it, the luminous matter of the photosphere seems to tumble pell-mell into the chasm, which disappears and leaves a disturbed surface marked with faculae, which in their turn subside after a time. As intimated before, however, the disturbance is not unfrequently renewed at the same point after a few days, and a fresh spot appears just where the old one was overwhelmed.

The spots usually appear not singly, but in groups—at least, isolated spots of any size are less common than groups. Very often a large spot is followed upon the eastern side by a train of smaller ones; many of which, in such a case, are apt to be very imperfect in structure, sometimes showing no umbra at all, often having a penumbra only upon one side, and usually irregular in form. It is noticeable, also, that in such cases, when any considerable change of form or structure shows itself in the principal spot of a group, it seems to rush forward (westward) upon the solar surface, leaving its attendants trailing behind. When a large spot divides into two or more, as often happens, the parts usually seem to repel each other and fly asunder with great velocity—great, that is, if reckoned in miles per hour, though, of course, to a telescopic observer the motion is very slow, since one can only barely see upon the sun's surface a change of place amounting to two hundred miles, even with a very high magnifying power. Velocities of three or four hundred miles an hour are usual, and velocities of one thousand miles, and even more, are by no means exceptional.

The average life of a sun-spot may be taken as two or three months; the longest yet on record is that of a spot observed in

1840 and 1841, which lasted *eighteen months.* There are cases, however, where the disappearance of a spot is very soon followed by the appearance of another at the same point, and sometimes this alternate disappearance and reappearance is several times repeated. While some spots are thus long-lived, others, however, endure only for a day or two, and sometimes only for a few hours.

As to the causes of sun-spots Doctor Abbot says (*The Sun,* p. 188):

> The causes which produce sun-spots, being as yet doubtful, or perhaps it is better to say *entirely unknown,* the causes of their periodicity and of the irregularity of the periods are, of course, also unknown. Attempts have been made to connect the period with the times of revolution of the planets, and, indeed, the mean length of the sun-spot period is not far from the period of the revolution of Jupiter (11.86 years). No satisfactory case for a connection between these phenomena is yet made out.

During his total eclipses the sun is seen to be surrounded by a pale luminous veil, called the *corona,* which during sun-spot periods is fairly regular all around, but in the quiescent periods is confined to his equatorial regions. It has been remarked of the corona, as matters requiring explanation; first, that it appears to partake of the uniformity of the sun's rotation, and, second, that comets which have been observed to pass through it suffered no retardation.

The *chromosphere* is a layer of incandescent gases having a distinctly reddish tint, and comes next below the corona; but whereas the latter is never observable except during total eclipses, the former can be seen at any time with the aid of telescope and spectroscope combined. Hydrogen is its chief component.

The so-called *prominences* or *protuberances* are upward projections in the chromosphere, but exist only temporarily. They are of two kinds, eruptive, which arise from some violent explosive action, and quiescent, which assume graceful tree-like forms and seem rather to evolve than spring.

Next beneath the chromosphere comes the *reversing layer*, relatively dark, of uncertain depth, and containing the cooler gases which are responsible for the Fraunhofer lines in the solar spectrum

And, finally, the shell or layer that will engage our attention here most, and which holds within it the key to them all—the *photosphere.*

We see, then, from the premises, that the sun presents not one only but a complexity of enigmas, all of which must be solved *consistently with each other.* His longevity; his occasional lapses and recoveries; the intensity of his light and heat; his density; his eruptive character; his sun-spots; their periodicity; his corona; its unresistingness; his absence of oblateness; his axial rotation *per se;* the cause of his equatorial acceleration; his share in the genesis of his system; his beginning and his destiny; his dynamical relationship to the stars in general; his relationship to comets and meteors; his path in space; the source of his magnetism; his connection with such terrestrial phenomena as earthquakes, electrical storms, climatic reversals, and the like—all these we shall treat of in detail and prove them intimately and causally interdependent.

## *SOLUTION OF THE SOLAR PROBLEMS*

One of the many serious objections to the Nebular Hypothesis is the fact that the residual mass, to wit, the sun, does not revolve on its axis with anything like the velocity demanded of it. According to Kepler's third law, this velocity should be at least 200 times more rapid than it is in nature. Furthermore, according to Laplace's idea, the entire solar body should revolve as a rigid solid, notwithstanding the mobility of its component materials; whereas there is noted a decided *acceleration of the equatorial regions,* amounting to as much as ten per centum over what it is in the middle latitudes. Attempts have been made by both Chamberlin and See to account for this phenomenon; the former by supposing that his ancestral sun may have had a different direction of axial rotation prior to its encounter with the strange star, and that both this old and the new rotation imposed by the encounter persist together; while the latter attributes the phenomenon to the infall of meteoric matter.

The explanation that I submit is this: Under the principle of equilibrium as hereinbefore expounded, the sun is the king-pin of the self-balancing, rotating machine known as the solar system. As a member of that system, he is obliged to aid in this balancing process to the extent imposed upon him by Nature. Between him and the planets, however, there is this fundamental distinction, namely, that whereas the planets have but *one* way open to them—orbital movement—whereby they can comply with the equilibristic law, the sun, being in the very center and *astride the fulcrum,* has *two* ways, to wit; first, by axial rotation and, secondly, by oscillating or "see-sawing" to and fro across the fulcral point. Now, we all know that however complex and multidudinous her operations, Nature never forgets herself or becomes confused, but carries all her processes along automatically and concurrently in perfect harmony. Accordingly, the sun does not choose either of the balancing methods open to him to the total exclusion of the other, but pursues both of them consistently. Is it not obvious, then, that, on this theory, the equatorial rim of the sun *being farthest from the center* should partake more of the orbital nature of movement, while the more central parts, *being closer to the fulcrum,* should seek the more direct course of shuttling? Of course, were the sun a rigid solid, he would necessarily rotate as a whole; but he is far from answering this description, being, on the contrary, fluid throughout, so that all his parts are measurably free to follow their respective equilibristic impulses.

Pursuing this train of reasoning further, let us conceive the sun severed in half on the line of his equator and then study his internal evolutions, fixing our attention now, not on his structure, which will be specially treated later, but on the torsional stresses that intestinally afflict him. To aid in clarifying the explanation, let us assume the section thus presented to view to consist, from center to circumference, of many concentric layers; then would all of these layers possess *some* velocity of rotation about the sun's axis, and in the same sense. However, not one of these would rotate uniformly with its neighbor on either side, but each would travel a shade *faster* than the adjacent *inner* layer and a little *slower* than the adjacent *outer* layer; producing by this process an enormous amount of *friction.* It is to this friction that I attribute the ELECTRICAL *and magnetic qualities of the sun.*

While thus we have the solar interior exposed to view, let me utilize the occasion by pointing out several other peculiarities in the sun's structure. One of these concerns the *distribution of his density.* Granting that the chemical constitution of the sun, qualitatively and proportionally, is identically the same as the earth's (as we have good grounds for assuming) and bearing in mind that the advantage of self-compressional power lies overwhelmingly in his favor, why is it that his density instead of being decidedly greater than that of our earth is only a quarter of hers? It is all well enough to say that the difference is due to the patent fact that the sun is vastly hotter than our planet, that the application of heat alters the state of substances from solid to liquid and thence from liquid to vapor, or gas, and that in each of these several states the volume of the given substance is greatly altered; but all this is only empirical, and not enough. Though *solids* and *liquids* do indeed expand and contract with heat, they do so only within very narrow limits; but *gases* derived from them seem to possess incredible expansive capabilities. Clearly, the distension of the sun cannot be accounted for on the score of expanded solids or liquids *as such,* but must seek its explanation solely in the *buoyancy of gases.* But here we meet with another difficulty; the sun, though very much lighter, bulk for bulk, than the kernel of the earth, is still 1.4 times *heavier than water;* how, then, could the gases exist *as gases* in a space *less than their own liquids would require?* Besides, who can guarantee that a ball of gas the size of the sun, or for that matter a gaseous ball of *any* size, *unconfined,* will preserve its identity and remain intact and globular?

Doctor Abbot assumes that the sun is *entirely* gaseous, but refrains from discussing the manifest objections to that assumption. It is a fact known and commented on by every solar observer, that at least the larger sun-spots preserve their identity, and even their outline, for weeks and sometimes months on end, and it is authentically recorded that the great spot of 1840-1841 lasted as much as eighteen months. How Doctor Abbot and other Doubting Thomases, beholding these wounds in the sun's side, can perversely persist in declaring him not matter, but matter's ghost, is beyond my fathoming.

Many scientists—probably the majority of them—appear to believe in a fourth state of matter, as some mathematicians do in a fourth dimension. The reason for this hypothesis lies in their endeavor to specify an effect for the enormous pressures brought to bear on the central parts of such immense bodies as the earth, Jupiter and the sun. Some have gone so far as to invent a description of this supposititious state—just as they dogmatize about the nature of the ether—and picture it as of a "waxy" consistency. A little reflection ought to convince these philosophers, not only of the unlikelihood of such an anomalous state of matter existing, but also of its *undesirability* from the standpoint of theory. The mystery here demanding solution is the sun's *lack of density,* and this mystery is only rendered altogether impenetrable by imagining his figure packed solidly to the core.

Mature deliberation on the problem of the solar density can lead to but one satisfying conclusion, a conclusion, too, that leads us by a well-blazed path to the clearing-house of practically all the present enigmas of the sun and stars.

To begin with, physicists have demonstrated by practical experiments that there is what they call a *critical point in gases;* signifying that, given a certain temperature (varying, of course, with the substance), no application of pressure, however great, that may be brought to bear will avail to reduce the gas to the form of a solid or liquid. Now, if this generalization is valid, then it necessarily follows that the *heart of the sun is gaseous,* since there *the temperatures prevailing are* *demonstrably above the critical point of every known chemical element.* But though the *interior* of the sun is gaseous, it does not follow that the whole globe is. On the contrary, when we consider his high internal temperatures, and his high density as compared with what he ought to possess were he in a solely gaseous state, we soon come to realize that the sun can be nothing else than an enormous *inflated solid* or *liquid shell.* Not only does this conclusion obviate the postulation of a chimerical fourth state of matter, and account for the persistence of sun-spot identity and the enigmatic low density of the sun, stars and planets, but, as we shall presently see, it also supplies the clue to practically every mystery of star-life and star-behavior from the moment the star crystallizes out of the nebular dust until it dissolves into nebular dust again.

After all, what is this doctrine of the critical point except a general recognition of the *explosibility of all substances by percussion, or crushing?* Dynamite may be detonated by raising its temperature, by a sudden blow, by friction, or by strong pressure. *So may any and every other substance.* "Give me," said Archimedes, "a lever long enough and I will move the earth", and so I say, give me a *press* powerful enough and I will detonate any known substance, whatever be its temperature, from gunpowder to granite. Apropos of this statement let me quote from the pen of that world-wide authority, J. W. Gregory, Professor of Geology at the University of Glasgow (*Geology of To-day,* p. 157):

> The ordinary rocks on the earth's surface are crushed into powder when subject to a weight of somewhere between two and thirty tons to the square inch. Hence if a column of ordinary rocks were built from 3 to 5 miles high, the base would be crushed by the weight of the upper part. Rocks are often found in such a condition of strain that they fly to pieces when exposed on one side in a deep mine. In some mining fields the rocks cut through in driving a mine tunnel suddenly explode owing to the strain of the overlying weight, just as a spring may snap when overloaded. Fragments are thrown from the rock face in 'rock blasts', and have caused many fatal accidents.

This detonation of rocks (and other materials as well, including metals) is no more than should be philosophically expected. That the three states of matter, solid, liquid and gaseous, *must follow each other in a cycle* at peril of destroying Nature's very life seems all but axiomatic. Were the fact otherwise, matter, once caught in the trap of gravitation and held down by superincumbent layers, would become perpetually staled and nullified; which is repugnant to sound reason. We know from experience that the heavier the pressure brought to bear, the less space does the compressed substance occupy. Were this rule to apply indefinitely, it would mean nothing less than the final extinction of matter by shrinkage into no space at all. Where does this trend cease and the recovery begin? How does Nature restore the balance? What logical thing remains for the tortured molecules to do, but to rebel and bombard the walls of their prison till these yield as to an acid and vouchsafe escape?

Heretofore it has always been assumed as quite a matter of course that matter thus gravitationally entrapped in the interior of cosmic bodies is forever rendered subservient to the ever accumulating material overhead. It seems never to have suggested itself to the minds of the physicists that the burdened materials could ever find a way of release. Yet what deduction could be more simple than that, given a sufficient body of rock ripe for exploding, it would not need to await emancipation from the tardy hand of man, but, seeking the path of least resistance, would tear its own way, here or there, through to the surface? It is in this essentially explosible nature of matter, under varying pressures, that I find the chief cause of volcanic eruptions and earthquakes, and the solar eruptions.

Now, explosiveness is characterized by the abruptness of its happening. When the critical condition within the bowels of the earth is well advanced, but not yet altogether ripe for a spontaneous letting go, the impending catastrophe may be precipitated by some foreign agency, as, for example, by a great *solar* eruption—*how* will be explained later. The point to be impressed in this place is, that the exploding crisis is not indefinitely deferable, and that, sooner or later, the explosive tendency within the sphere catches up to and finally overwhelms the repressive forces. The effect of these belchings out of the earth's interior is to relieve the distension of her crust in the neighborhood of the orifices of escape and allow subsidence to the normal level; following which event the gases go on accumulating again, until the like action is repeated—a sort of earth-breathing, one might say. This alternate subsidence and elevation of the earth's crust is a long-standing scientific curiosity, and has heretofore been sought to be explained by the so-called principle of *Isostasy;* meaning, that the various areas of the earth's crust are equilibrated against each other. That this principle of isostasy is fundamentally sound, it seems to me, should go without saying; only it requires to be treated, not so much as a prime cause as a concomitant one of minor potency.

## THE ANATOMY OF THE SUN

Returning again to the sun, my conception of him is that of an enormous bounding shell of molten matter enclosing and mightily compressing an inner spherical chamber of superheated gases, whose buoyancy, in turn, supports the shell. In short, the sun is, in principle, constructed on the order of the soap-bubble, only his walls are proportionally far thicker.—How thick?

It can be shown by a very simple calculation, based on the rule that the volumes of spheres are to each other as the cubes of their diameters, that were the third-of-a-million earths that compose the sun crowded, in their solid state, into his outer part, they would make a shell about 47,000 miles thick, equivalent to one-fourth his present volume. Of course this cannot be the case actually, seeing that these counterparts of our earth, as we are assuming them to be, are largely composed of substances too volatile to be able to resist the high solar temperatures. Moreover, we must allow for the weight of the gases occupying the central reservoir, and for the weight, also, of the solar atmosphere. It is not altogether guesswork if we allow for these claims about one-half the shell's thickness, reducing the latter to, say, 25,000 miles, in round numbers.

A few peculiarities of this shell demand attention. One of these has to do with the observed inclination of the sun's axis, which *prima facie* should, according to my theory of the stellar resultant and systemal equilibrium, parallel the axis of the earth. As a matter of fact, however, the solar axis is inclined, not 23-½°, but only 7°, to the plane of the ecliptic. What explanation can there possibly be for this apparently fatal discrepancy?

My answer is this: that were the sun *rigid* to the same degree as the earth, he would undoubtedly, like Mars, lean as does the earth, but *not* being rigid, he ceases *ipso facto* to be a trustworthy criterion of the main question. Prior to the ocular discovery of the sun's equatorial acceleration, and that from his middle latitudes to his equator this acceleration is gradual and continuous, and even reducible to a formula, what astronomer would have supposed such a thing physically possible? When, therefore, I say, as I now do, that the solar shell consists of *many plies, and that each ply has its own velocity of rotation and its own* PLANE *of rotation,* it may sound quite as incredible to the same ears. According to my interpretation, the *innermost* ply of the solar shell revolves about an axis nearly, or quite, *parallel with the axis of the earth,* while his *outermost* envelope, at the equator, revolves about one that nearly approximates a *perpendicular to the plane of the planetary orbits.*

A second peculiarity about the sun that is not true of the earth is, that the former exhibits no oblateness of figure whatsoever, but presents at all times a sensibly circular disc. Were the sun as rigid as the earth, he would be flattened at his poles, but, *because of his inflation,* his rotundity is being perpetually retrimmed. The ball of our planet lacks elasticity and, as in the case of a ball of putty, its settling and flattening become more and more confirmed as time goes on. Were a close physical examination of the sun humanly possible, it would be found that the northern end, or base, of his shell is appreciably thicker and heavier than its southern, but this in no way affects his external symmetry, inasmuch as his interior buoyancy maintains his shell exactly centered upon his center of mass.

## THE SOLAR PROCESS

Without pausing at this juncture to point out the *source* of the sun's heat, save to assert that it is a function of his mass, and judging him simply by analogy with the earth, whose temperature increases with the depth, we are justified in assuming that *his* temperature, too, rises steadily from his photosphere to his center. This naturally prompts the query as to what effect this condition has upon the character of the shell's chemical composition at the various depths. A preliminary illustration may assist in clarifying the answer:

Suppose you were handed a mixed pailful of finely pulverized, insoluble materials known to contain equal parts of ten different minerals, all evenly graded in an ascending scale according to specific gravity; how would you go about the task of separating them? Without bothering to cast about in our minds for an artificial way, let us put the burden on Nature and see how she would do it. We will search for a very deep and narrow well and, finding it, we will dump on its surface, as abruptly but as gently as possible, the entire contents of the pail, then with the eye of imagination, to which all things are transparent, watch the result. We will suppose, further, that the water in the well is just 10 fathoms deep. Clearly, there would ensue an interesting race between the ten substances for the bottom, in which contest the test of fitness would, of course, be that of weight, or more technically speaking, *specific gravity;* and when the affair has been concluded we shall find, piled up on the bottom, a column of ten thin layers ranged in the order of their heaviness. But what of the status of the race at its various stages? In the first fathom, beginning at the top, we shall see all the ten minerals inextricably mingled, but in this stretch the lightest of all will become so distanced that in the second fathom we shall be able to distinguish but nine sorts, in the third but eight, and so on until the heaviest particles begin to touch bottom.

Now, something of this sort occurs in the shell of the sun, except that here the tests of fitness are *two* instead of only one, and these two are, first, specific gravity (perhaps it were more accurate in this case to say *atomic weight*), and, second, *refractoriness,* or resistance to volatilization. Imagine now, if you please, the earth ground into fine powder and sprinkled over a limited area of the solar surface, and for the sake of simplicity suppose, further, this powder to be classifiable into ten distinct grades, as in our previous illustration, and, lastly, suppose the solar shell to be likewise differentiated into ten successive strata with temperatures progressing downwardly. Is it not obvious, now, that there would here ensue a process of *distillation,* a sort of refining or smelting process, in which the diverse materials would, in the order of their volatility, *be successively driven off* as they sank (by reason of their avoirdupois) into lower and lower levels of *higher and still higher temperatures?* It follows, then, as a matter of deduction, that the lining of the central chamber of the sun, or shall we say its face-wall, is almost, if not quite, *homogeneous* and composed of a substance all but perfectly *refractory,* and that thence on outward the layers gain steadily in *heterogenity* until we reach the surface.

In this process we see that the sun is something *more* than a dispenser of light and heat; he is also a *smelter* of minerals, providing man with the ores, which may not inaptly be termed *cosmic pig metal.* How these materials reach the earth we shall presently discover; for that they do, and that they have reached her in comparatively recent times is sufficiently attested, not only by the fact that these heavy ores are to be found here in "veins" and "pockets", but that they are to be found *on the surface.* Had the earth been originally her present size, and molten, the heavier materials must inevitably all have sunk toward her center and only froth and scum remained to blanket her.

Though I have spoken of the sun's strata, both in discussing his differential rotations and the chemical constitution of his shell, and shall yet continue so to speak, yet I wish the reader to understand that there are no sharp lines of demarcation between them, but that the changes up and down, though certain and pronounced, melt imperceptibly into each other. The reason lies, of course, in the great variety of the natural chemical elements and compounds, and in their abundance in the solar economy. Assuming that the graded temperatures of the shell, level by level, are invariable, and that the pressures are equally so, it follows *that every element and compound regularly explodes every time it reaches its particular critical depth.* Such explosions necessarily cause eruptions through the photosphere, giving rise to jets, geysers, fountains, or prominences, whichever the reader may think best to call them. In proportion to their deep-seatedness and severity, these explosive gases not only change places themselves, but they carry before them in their outward rush great quantities of debris from the intervening layers to greater or less heights beyond the photosphere, whence, being normally condensed and turned back by the cosmic cold, they rain down upon the photosphere in a ceaseless hail of slag and cinder—only to begin the same process over again.

*Briefly, then, the solar process consists in the continuous explosive conversion of the sun's interior substances into gases by virtue of the pressure of the superincumbent layers falling toward his center, the space allowing for such fall being vacated by the said gases, which rise to the surface upon the wings of their own explosive force, there render up their heat, condense, and regain their original energy of position as part of the great solar press—an unending cycle of mechanical combustion and gravitational resynthesis.*

This cyclical process of converting gravity into heat and heat into gravity again, finds a remarkable parallel in the terrestrial transformation of water into vapor, rain and ocean, of which were one link unknown it would be infinitely more difficult to divine. In the solar heat-generating cycle, the descending jets, or geysers, answer to our rain, perpetually flooding the whole of the sun's surface, and falling, with the regular continuity of the Amazon, toward his interior, there to suffer "evaporation" by his self-pressure instead of by his rays and thence to rise again in fountains of life-giving warmth.

It is plain to be seen that the shorter the distance that a substance must sink before reaching its critical level, the shorter the cycle of its action and consequently the more frequent its periodical eruptions. On the other hand, for that very reason these superficial eruptions are proportionately mild. It is from the *pinnacles* of these jets—ever freshly new, incandescent, and unencrusted—that we derive our extraordinary supply of light and heat. In short, they *pump* us heat and light, as it were; which accounts for two things; first, for the puzzling intensity of the solar radiations, and, secondly, for the keeping measurably cool, by their "exhaust", the magma from which they issue. They are *double-carriers*, as it were, conveying their cargoes of heat out into the cold sky, exchanging there their cargoes of heat for cargoes of "cold", and bearing these latter back for the sun to expend his excess energy upon.

The so-called "rice grains" of the sun are nothing more or less than the geyser pinnacles above mentioned. They are the ephemeral ebullitions in the magma, appearing and disappearing in endless repetition and profusion. Of these Professor H. H. Turner in his *A Voyage in Space* (p. 214) says:

> By a tragic accident he [M. Hansky, a Russian astronomer] was drowned, and no one else has paid the same attention to photographing these rice grains on the sun; but he obtained a sufficient series of pictures to show at what a great rate they are moving about. Even in a few seconds the pattern becomes quite differently arranged, as you can see by comparing one of M. Hansky's pictures with another. They must be moving at great speed, some of them perhaps at 100 miles a second * * * The whole surface of the sun is in a state of constant turmoil.

And on p. 244 he adds:

> When I tried these different ideas, I concluded that the particles (in the corona) were behaving as a fountain behaves, being both shot up and falling down again * * * My conclusion is that there are a large number of solid particles in the corona, because there is a great deal of polarized light; and other astronomers have found the same thing.

So much for the *superficial* eruptions, but what of those more deeply seated? The cycles of these are naturally longer; all the more severe too, for that very reason. Late researches have led to the knowldge that the "solar constant" is not so constant after all, but varies rhythmically by periods of five days, of ten days, and so on, proving the occurrence of *fluctuations in the sun himself. All of these variations are easily accounted for by postulating a series of eruptive levels, each with its own characteristic interval of manifestation.*

## THE SUN-SPOTS

One of the periods of which we have been speaking is, of course, that of the sun-spots. In this phenomenon we have an example of sufficient distinctness and legibility to enable us, by a close study of available data, to determine the solar level from which it emanates. This is not exactly an easy task, for the reason that, as before stated, the blast carries before it in its ascent vast quantities of miscellaneous debris from all of the superior layers which requires to be differentiated out. The test, of course, consists in discovering *which is the most refractory* element or group of elements most conspicuously represented in the pertinent spectra; and a good deal also depends upon the *age* of the spot at the time the spectra are obtained.

Some may infer that I mean that these deep-seated blasts occur sporadically, and without any preliminary preparation of the surface. I do not mean this especially, though I admit the possibility of such happenings. The time being ripe for the coming event, I presuppose, rather, a series of eruptions, from the top layer to the next, and so on, opening a path of least resistance down to the lowest layer affected in each individual case. With each succeeding deeper detonation the original superficial vent is widened more and more until there yawns at last a well thousands of miles in depth, ripped through from below. This remains open until the internal pressure is sufficiently relieved, and then ensues a falling and filling in until the gaping wound is completely healed. That the girth of the sun should diminish slightly as a result of these belchings is self-evident, but the difference is too small to have been measured, though Professor Poor, it seems, has detected some such difference.

Owing to the differential rotations within the solar body, as previously described, and the friction caused thereby, the pent up *gases are electrified* before their escape, and, after escape, rising hundreds of thousands of miles above the sun's surface, they produce and perennially keep in repair the coronal veil that envelopes him. "There is a cycle of changes", says Doctor Abbot, "supposed to be identical with that of sun-spot frequency. As the corona can be observed only at total solar eclipses, the march of the cycle of changes is as yet only imperfectly known, but for the last half century it has been observed that there are long equatorial coronal streamers at the time of sun-spot minimum while at maximum of sun-spots the corona extends only to moderate distances but nearly uniformly in all directions from the sun". A comparison of the photographs he gives (*The Sun,* pp. 132, 134) will show that at sun-spot maximum the corona is *very much more dense* than at minimum, confirming the justice of my assertion that it is the emanations from the spots that renew the veil. Heretofore the Newtonians have shrunk from admitting this very natural conclusion, realizing as they did the impossibility of reconciling a materially dense corona with the non-retardation of the comets that have been seen to traverse it.

It has been observed, time and again, that solar eruptions on a grand scale are usually accompanied by *mag-*

*netic disturbances on the earth,* by *tidal waves,* by *earthquakes,* or by all of them together, and the causal connection has until now been one of complete mystery. It has, indeed, been suggested that the sun at such crises is exceptionally charged with electricity and that this somhow finds its way across the void; but this idea is recognized to be far-fetched even by its proponents. The true explanation is this:

Some sun-spots have been observed as much as five times as wide as the earth, and there have furthermore been witnessed from time to time solar eruptions upward of 200,000 miles in height, with initial velocities exceeding 100 miles a second. Such convulsions as these necessarily portend a substantial *displacement of the center of mass of the sun* and *ipso facto* of the entire solar system, and cause perturbations to every individual planet, satellite and comet within the latter, including, of course, our earth. This is *bound* to be the case, whether we view the planetary system in the conventional light of Newtonian astronomy or in the new aspect of an equilibrating unit. To make use of a homely simile, the sun at such times is like a great spider in the act of shaking his gravitational web. Now, (to change the figure) although we, the passengers, on this great ship may not be able to sense these perturbations directly, yet *the earth herself does,* and so while the solar convulsion lasts, she gently wavers in her orbit and sways upon her axis in rhythmical sympathy with her stricken lord. The inevitable result is that the oceans are caused to shake profoundly in their huge basins, producing not only tidal waves, but also, *by the friction on their beds,* augmenting the supply of electricity normally furnished by the diurnal tides. The effect of these perturbations on the solid parts of the earth is sometimes, though perhaps not usually, accompanied by earthquakes. The reason for this is not that the perturbations are the *vera causa* of, but that they precipitate, earthquakes nearly ripe for spontaneous manifestation, much as the slamming of a door may cause the glowing coals of a grate fire to collapse when near the point of doing so of themselves.

Knowing as we do by ocular evidence of the habitual periodical occurrence on the sun of these eruptions, big and little, the question suggests itself whether the sun may not be subject, *at longer intervals than we possess records of, to vastly greater convulsions.* A phenomenon that seems to lend color to this inference is that of "new stars". "These", says Doctor W. W. Campbell, "appear with great suddenness at points where previously no star of catalogue brightness (that is, as bright as the ninth magnitude) was known to exist, and occasionally, according to photographic observations, where no star as bright as the twelfth magnitude was recorded. They reach maximum brilliancy in a few days or a few weeks, pulsate through a considerable range of brightness for a few additional weeks, and thereafter decline more or less continously until they become comparatively faint stars. In some cases they assume approximate constancy as faint stars, and in others they seem to go beyond the reach of telescopic power, and later become visible again as faint objects". What is thus clearly true of some stars may reasonably be true of others, and of our sun; not simply once, but *repeatedly.*

Just such cataclysms as these have, as a matter of fact, occured again and again to our luminary in the long geological past; not all of them, of course, equally severe, yet comparably so. Violent though they are, however, they are far from being total, nor should it be inferred that they occur at *regular* intervals any more than do the sun-spots. It is to these solar backslidings that I attribute *the alternation of genial- and ice ages,* for which scientists have so long been groping for explanation in vain; and to them do I also attribute, in chief measure, *the enormous alterations of continental levels* ushered in with the glacial epochs. Obviously, the sudden liberation of a great store of high-temperature gases would greatly reduce the sun's radiation for a long time to follow, and centuries would probably pass before he recuperated to normal, and still other centuries ere he could succeed in dissolving away the glaciers accumulated during his prolonged lapse. As for the changes of level, these may easily have been due to the convulsive shakings of the solar web. These would, as a matter of course, precipitate earthquakes on a grand scale, fracturing the crust in a multitude of places; and through the fissures thus created the imprisoned gases would make haste to escape, thereby not only giving rise to numerous *volcanoes* and much *fouling of the atmosphere,* but incidentally letting down the previously distended crust. Nor should we here neglect to take account of the *lateral stresses* due to the gravitation of the land masses toward the north pole, for it is just at such a time of equilibristic readjustment as this that this lateral pressure should make itself most felt and improve the occasion by *raising up the great mountain chains.*

The problem as to just how often these central explosions of the sun occur may find its answer in the response geologists shall give to the question as to the frequency of ice ages. If, in the absence of definite knowledge, we assume the earth to be a billion years old and the average interval between successive ice ages 100,000 years, there should have been, to date, 10,000 such ages and 10,000 such cataclysmal explosions. It is very doubtful, however, whether geology, on account of obliterations of its records, can supply a surer answer to this query than solar physics may more directly and speedily yield.

With the escape of the buoyant gases from within him, the sun would naturally collapse upon himself, and there would follow a long period of rejuvenation during which his radiation, color and brilliancy would all be those of a *star of lesser mass;* and during this same period, which must be regarded as an abnormal and fitful stage, he would, furthermore, exhibit fluctuations in all the three attributes mentioned, making of him, for the time being, a *typical variable star.*

Although solar and stellar explosions are automatically produced by the causes just outlined, it does not follow that these are the *sole* agents. There must always lie in the back-ground the possibility of collision, not so much with another star, which is a very remote possibility indeed, but with a great comet. The comet of 1840-1841 *may* have been such a one, and had it been fired by its parent star a shade more accurately, it might have struck the sun amidship, punctured his inflated integument, and precipitated upon us a dire calamity.

## *THE GENESIS OF THE SOLAR SYSTEM*

In such catastrophic explosions of the sun, then, be their causes what they may, we have the secret of the genesis of the nuclei of the planets and the method by which these nuclei have been gradually built up into the great bodies we now see. The planets were not created full-grown and full-panoplied, but they have added layer on layer, development to development. Indeed, every biological and geological fact proclaims the truth of this dictum, as every well-informed scientist will freely concede. The objections to the hypothesis of self-explosion on the part of the sun in the past and its heretofore total exclusion from consideration, have not been on account of any intrinsic defect, but because it left out of the reckoning the origination of the rotatory motions of the systems and, besides, contravened the dogma of the conservation of energy. The first of these objections is met by the newly-discovered principle of the Prime Resultant; the second will be considered in a following chapter.

The pent-up gases, escaping as they do in these catastrophic cases from under a hydrostatic pressure of millions of atmospheres, in tearing their way through the superincumbent 25,000-mile shell naturally carry with them billions upon billions of tons of solar magma in various stages of metallurgical reduction, according to the solar level from which they respectively emanate. No doubt the major part of this upheaved material falls back upon the sun, but a vast amount of it is carried on outward—past Mercury, past Venus, past the earth, on even to Neptune, the outermost planet—spreading itself into a disc-shaped nebula as it goes; disc-shaped because the sun-spots are known to seek the solar equator. Indeed, some of these ejecta do not even remain within the system, but forge onward into space, distancing the solar gravity, as it were, and finally cross the border line of neighboring systems, there to become the cometary and meteoric vassals of other suns and stars. Inasmuch as the repulsive force is single, and the ether of space opposes no resistance, we should naturally expect that the outer planets would be fed proportionately more of the lighter materials of the solar carcass, and *vice versa* as to the planets nearer him. At any rate, this accords well with the physical facts, for the superior planets are by far the least dense.

The violence of the ordeal ended, the nuclei originally, and now the matured planets, under the gyratory rule of the Prime Resultant, continue on in the even tenor of their way and proceed to sweep up by their gravitational suctions the nebular material littering their respective orbital zones. It is quite true that the nebula, under the principle of systemal equilibrium, tends from the first to accomodate itself to the Keplerian law of areas, in which case, if that goal were *immediately* realized, the ingathering process would be defeated; but it is also true that this adaptation requires a long period, during which the *differentiation of orbital speed* between the coursing planets and the relatively stagnant medium immensely facilitates the gleaning process. In spite of this advantage, however, wisps of the most tenuous matter will always remain uncaptured and continue to litter the zone of the ecliptic indefinitely. These wisps, being illuminated by the sun outside the boundaries of the earth's shadow, are responsible for the phenomena known as the *Zodiacal Light and Gegenschein.*

When I say that the *planets* devour this nebular matter, I do not mean to exclude from the cannibalistic feast the asteroids, satellites, or even the meteors, that help to make up our system. All of these share impartially, according to their respective gravitative voracities. Furthermore, they stand the same risk of being struck by the flying missiles. This suggests the question as to what should be the direct effect upon terrestrial life were such a catastrophe as I have described to take place *to-day.*

Granting that the earth is the built-up product of 10,000 such contributions from the solar mass, and that the same thing is true of all the rest of the planets and satellites, then, since all these together equal 1-750 of the sun, it follows that the latter loses on each such occasion only 1-7,500,000 of his corpus, or, say, 1-20 of an earth. Since the earth's disc, as previously computed, intercepts only 1-2,000,000,000 of the sun's light, of course it would likewise intercept only the 1-2,000,000,000 of 1-20 of six sextillions of tons of weight, or 150,000,000,000 of tons—equal to 750 tons to the square mile, or, say, 1.25 tons to the acre, taking in the entire area of the earth's surface. Of course this solar hail would not be evenly distributed, unequal fragments being promiscuously scattered here and there, while the *night* side of the planet and other sheltered places might escape scot free. The real increment to the planet's growth would not be acquired by this direct bombardment, but by the subsequent slow gleanings from the nebula.

# X

# THE STARS AND NEBULÆ

"HE made the stars also" is the curt phrase with which the Mosaic cosmogony dismisses these wonderful diadems of the sky, and, milleniums later, the great Newton himself knew nothing to add about them in the way of definite knowledge. During the past century, however, beginning with Bessel's and Henderson's successful determinations of the parallaxes of *Alpha Centauri* and *61 Cygni* in the 1830's, the discovery of the principle of spectrum analysis by Kirchhoff in 1859, and Sir William Huggins' application of the Doppler principle to the study of spectra for determining the radial velocities of stars, in 1868, immense progress has been made—but, only, be it frankly said, in the way of gathering material, rather than in the work of actual construction. Let me particularize:

## STELLAR MOTIONS

First, as to stellar motions. I trust I am not misjudging the aims of astronomers in supposing that their detailed study of individual stars and of their several proper and radial motions is not esteemed by them an end in itself, but a stepping stone, merely, to an ultimate understanding of the organic constitution of the universe as a unit and a system. Indeed, if the latter be not the true purpose, and if the mere multiplication of unclassifiable and unintelligible data of such things as, observations on variable stars, star spectra, radial motions of stars, proper motions of stars, distances of stars, magnitudes of stars, and the like, is the *sole* end in view, then in the name of common sense and wholesome economy let the farce be stopped. There is but one way to justify all this labor and expense of accumulation and to lift work of the same sort in the future above the plane of drudgery and mental dissipation, and that is, by finding a noble and structural use for it all.

Suppose that mankind, notwithstanding all the investigations with telescope and spectroscope hitherto made, should have continued in the belief that the earth is the center of the universe and that the firmament revolves around it daily; what genuine value would all our *detailed* knowledge possess? The knowledge both of the earth's rotation on her axis and around the sun is absolutely indispensable to a sane interpretation of the solar system. *But it is no more essential to this purpose than is the knowledge of the form of the sun's path in space to a sane interpretation of the stellar motions and system.* It constitutes all the difference between truth and error, between a yes and a no, whether the sun is speeding in a straight line or in a curve. Doctor W. W. Campbell, Director of the Lick Observatory, to whom the world of astronomy looks for leadership in this special field, in his *magnum opus* (*Stellar Motions,* p. 194) thus antagonizes the hypothesis of the sun's path being else but rectilinear:

> These are frequent and legitimate questions: Is the solar system moving in a simple orbit, such as a conic section? Will it eventually complete a circuit in this orbit and return to the part of its orbit where it is now? The idea of affirmative answers to these questions appears to be prevalent in the human mind. It is natural to think that we must be moving on a great curve—perhaps closed like an ellipse, or open like a parabola—the centre of mass of the universe being in the curve's principal focus. The attraction which any individual star is exerting upon us is certainly slight, owing to its enormous distance, and the resultant attraction of all the stars may not be very much greater; for since we are believed to be somewhere near the centre of our stellar, system, the attractions of the stars in the various directions should nearly neutralize one another, in accordance with the principle that a body situated within a concentrically homogeneous sphere is effectively acted upon only by the gravitational matter nearer

the centre of the sphere than itself. Even though we may be following a definite curve at the present time, there is, in my opinion, little doubt that we shall be prevented from continuing upon it indefinitely. In the course of our travels we should be carried, sooner or later, relatively close to some individual star whose attraction would be vastly more powerful than that of all the other stars combined. This would draw us more or less from our present curve and cause us to follow a different curve. At a later date our travels might carry us into the sphere of attraction of some other great sun which would send us away in a still different direction. Thus, the chances are, in my opinion, that our path would, in time, be made up of a succession of *unrelated curves.*

The results deduced above define the direction and speed of the *solar motion along a straight line;* and, as a single line does not fix the position of a plane, *we are without knowledge as to the plane in which the solar system is moving.* It is of great interest that the present line of motion lies nearly in the plane of the Milky Way, making in fact an angle of about 17° with the central line of the Milky Way. We need not concern ourselves at present with the question of the plane of our orbit, for the *curvature of our path is undoubtedly so slight that we may consider it as a straight line for many generations of astronomers to come.* (The italics are mine)

In giving utterance to these opinions Doctor Campbell has not only vented his own personal views, but has likewise stated the only logical conclusion that the Newtonian doctrines of uncaused motions and negation of equilibrium allow. About the only thing of great significance that this study of the proper and radial motions of stars—a study which represents a perfectly incredible expenditure of valuable time, skill, energy and money—has developed, is the *supposed* existence of star-streams, for which the investigators confess their inability to suggest any explanation, and *whose existence runs counter to every Newtonian tradition.* Under my system of interpretation *these streams are not streams at all, but an optical illusion created by the movement of our solar system in its gyroscopic course from east to west and the fall of the ecliptic;* much as the ancient notion that the heavens rotated daily around our earth was such an illusion. By parity of reasoning, the so-called vertices of preferential motion are likewise the effect of identically the same cause; and so, likewise, is the locus of the solar apex, as hitherto determined, apparent merely, and not real. The true course of the sun is that of recession (westward) from the celestial point of the vernal equinox along the equinoctial colure; the latter's length (186,000,000 miles) constituting an arc of about 50″.2 of the sun's orbit, having its concave side toward the position of our earth in winter, and continually sinking toward the Vertex, or gravitational pole of the ecliptic, at the rate of some six miles per second. In attempting to visualize this description and to truly appraise the illusory character of these "streams" the reader is cautioned to take into the reckoning the phenomenon of precession *at its face value,* and not to discount it, as astronomers now do, under the rulings of Newton's misconception of its cause. The sun, under their conception, should *seem* to tend toward R.A. 270° and Dec. +33°.23, but his actual path is as I have described.

Generally speaking, the movements of stars are far too slow, and the labor of ascertaining them in the first instance, and of afterward piecing them together, far too tedious and difficult, ever to make the general mapping out of the stellar field into minor individual systems well worth while or, perhaps, possible. Enough of this sort of work has already been done, however, and more is now in progress, to reveal the tendency of vast star-clusters to arrange themselves into spiral conformations, indicating the *operation of some common cause.* What, I pray, can this cause be other than gravitation—not *centripetal* attraction by itself, which logically should *destroy* the isolated system (all the faster because of its isolation), but that attraction *in combination with the stellar resultant* reinforced by the *equilibristic principle?* The clue to all such observed arrangements is to be found, if at all, in first determining as nearly as can be from observation the directions of the shortest axis and of the longest axis of the given cluster, and then angling for the line of the prime resultant that best fits the situation. In this connection it will be illuminating to compare this passage from Professor Proctor's book, already referred to (*Our Place Among Infinities,* pp. 201-202):

> Father Secchi of Rome speaks thus of the distribution of stars within a certain very bright portion of the Milky Way in the constellation Sagittarius, as revealed by the powers of the fine refracting telescope of the Roman Observatory:— "There are large stars and lucid clusters; then a layer of smaller stars certainly below the twelfth magnitude; then a nebulous stratum with occasional openings." But what startled him and all to whom he showed it, was the regular disposition of the stars in figures so geometrical that it is impossible to regard them as accidental. "They are for the most part *like the arcs of a spiral*; one can count as many as ten or twelve stars of the ninth and tenth magnitude—*following each other on the same curve like the beads on a rosary;* sometimes they seem to diverge from a common center, and, strangely enough, it usually happens that either at the center of the rays, or at the beginning of the branch of a curve, there is a larger star of a red colour. *It is impossible to regard such an arrangement of the stars as accidental."*

That scholastic astronomy, notwithstanding its wealth of detailed knowledge, remains primitively ignorant of the general principles governing the movements of stars, as well as of the structure and internal activities of the individual stars, and that some radical reform in astronomical theory is imperatively called for, will appear from the subjoined quotations. The first of these is taken from Doctor Campbell's book (p. 216):

> It is not easy to explain why the velocities of stars should increase with their effective ages, for we are accustomed to think of all matter as equally old gravitationally. Why should not the materials composing a nebula or a Class B star have been acted upon by gravitational forces as long and as effectively as the materials in the Class M stars? Are stellar materials in the antestellar state subject to Newton's law of gravitation? Does gravitation become effective only after the processes of combination are well under way? Is it possible that the gaseous matter composing a nebula is acted upon as effectively by radiation pressure as by gravitational attraction? The observed fact of the dependence of stellar velocity upon the spectral class is so new that these comments and questions make no pretensions to the status of a solution; but I am unable to suggest any other directions in which we should seek for the explanation.

And the second is from the recent work of Professor

A. S. Eddington, of the University of Cambridge (*Stellar Movements,* p. 255):

> The problems on which dynamics would be expected to throw some light are numerous. Why have the stars in the early stages very small velocities? Why do these velocities afterwards increase? In particualr, how do the stars acquire the velocities at right angles to the original plane of distribution, which cause the latest types to be distributed in a nearly spherical form? How are the two star-streams to be explained? What is the meaning of the third steam, Drift O? Can the partial conforming to Maxwell's law be accounted for? What prevents the collapse of the Milky Way?
>
> Some of these problems seem to be at present quite insoluble. Indeed, it must be admitted that *very little progress has been made in the application of dynamics to stellar problems.* What has been accomplished is rather of the nature of preparatory work. It has been shown that stellar dynamics is a different study from gas-dynamics, and, indeed, from the theory of any type of system that has yet been investigated. A regular progression may be traced through rigid dynamics, hydro-dynamics, gas-dynamics to stellar dynamics. In the first all the particles move in a connected manner; in the second there is continuity between the motions of contiguous particles; in the third the adjacent particles act on one another by collision, so that, although there is no mathematical continuity, a kind of physical continuity remains; in the last the adjacent particles are entirely independent. A new type of dynamical system has therefore to be considered, and it is probably necessary first to work out the results in simple cases and to become familiar with the general properties, before attempting to solve the complex problems which the actual stellar universe presents. This has been the mode of development in the other branches of dynamics.

## STAR STRUCTURE AND CHARACTERISTICS

Granting to all stars the same chemical constitution in kind and ratio, I hold that their temperature, density, velocity, color, and brightness are all *functioned on the mass,* and, further, that their spectra are *ordinarily* reliable criteria of their masses. By this I do not mean that there is any exactly *commensurate* relationship or correspondence between all of these characteristics, but merely that, the bigger the star the hotter its temperature, the thinner its density, the slower its velocity, the whiter (or more bluish) its light, the brighter it is, and the more refractory its normal spectrum. This rule is subject to one general qualification, namely, that all stars are liable to collapse (as a result either of spontaneous explosions due to clogged radiation, or of puncturing by flying missiles from other stars) and also to variations (e. g. sun-spots), which are in the nature of collapses, only minor in degree and quickly periodical in recurrence. In these collapsed or semi-collapsed states, the star, by reason of the sudden escape of great quantities of its superheated gases, drops for a spell into a lower order of stars, not so much because of the actual loss of substance, which is relatively insignificant, but because of its decided fall in temperature, whereby its phenomena are for the time being modified. We will now consider the various characteristics separately.

TEMPERATURE. According to current notions, based as they are on the doctrine of the conservation of energy, all the stars, the sun, and the planets are in the process of cooling down from an initial state of incandescence; hence, argue the scholastics, the duller a star the older. In the next chapter I shall attack this law of conservation and expose its hideous absurdity, establishing in its stead the proposition that *heat is a staple product of Nature's,* and that gravitation, as represented in quantity of mass, is a perpetual generator of it.

DENSITY. Were the density of every cosmic body the very same, then mass and volume could be treated in mathematical computations as synonymous terms. It is, however, far from being the same; each planet having its own particular density, the sun having his, and every star presumably having its. There must be some physical cause or causes for this contrariety, What are they? These three occur to me: (1) Difference in chemical constitution, (2) Self-compression, (3) Expansion by heat.

That there is considerable difference in the chemical composition of the celestial bodies—if not in the number of elements represented, at least in their relative proportions—seems altogether likely; but there is no way of ascertaining the extent of this difference in any particular case. Some of my readers may suppose this knowledge obtainable from the spectra of the stars, but these give no clue whatever as to either the *quantities,* absolute or relative, nor, since the revelation of an element in the spectrum depends on the temperature intensity, do these spectra even settle the problem as to the mere *number* of elements. Except, therefore, where we can assign some definite ground for hypothesizing otherwise, we have no option but tentatively to assume that all stars, if not exactly, are yet approximately *enough alike chemically* to validate comparisons between them on this basis.

Having thus ruled out the factor of differential chemical composition, not because of its immateriality but because of its indeterminateness, we are relegated to the two remaining factors of *self-compression* and *temperature.* These two I associate, making the latter depend on the first as a causal effect. Construing density to decrease with temperature increase, we may begin by imagining all stars cold to begin with, and all of them virtually of the same density. This last would, of course, not be exactly true, inasmuch as the larger stars, because of their more powerful self-compression, would necessarily pack their contents into smaller compass; but this, you can see, is a negligible consideration inasmuch as the condition requiring to be elucidated is not why the big bodies are *more compact* but why they are vastly *less compact* than the small. As said before, then, density being taken as initially the same for all bodies, mass and volume become synonymous, and we have for the ratio of the integral attractions of cosmic bodies in general the formula,

$$\frac{\mathrm{M}}{(\sqrt[3]{\mathrm{M}})^2} : \frac{m}{(\sqrt[3]{M})^2}$$

in which M is the mass of the large body, $m$ that of the smaller, and $\sqrt[3]{\mathrm{M}}$ and $\sqrt[3]{m}$ are their respective radii; the latter terms being *squared* and placed *under* the line in conformity with the law of inverse squares. Substituting, by way of illustration, the sun's mass for M and the earth's (unity) for *m,* and working the problem out, we shall find that the sun's integral attraction (were his density the *same* as the earth's, instead of only one-fourth, as it is) would be 69 times as great, whereas, computed on the basis of his *real* density, this ratio is only 27.6 to one! What, I pray, becomes of the tremendous surplus of this *potential attraction* (by which name we will hereafter refer to it) over the observed? So far as my reading has extended, I have found no suggestion about it anywhere, much less an attempt to fit it into the web of scientific theory. Yet what could be more likely *a priori* than that this surplus energy is utilized in the wise economy of nature for two things, first, to gaseously inflate the sun for certain cosmic ends, which I have already outlined, and, secondly, to generate the light, heat, and, *perhaps,* magnetism that is radiated so lavishly to the planets? Without going into the complicated minutiæ, it can be shown by mathematics that the *density of stars diminishes as the "potential attraction" increases,* and in making this statement I am not unmindful of the apparent, but *only* apparent, contradictions of some of the planets; and by the same process of computation, it can further be proved that the shell, though it increases in *absolute* thickness, *diminishes relatively to the length of the radius, with the star's growth.*

(In passing, be it said, the reason why the sun's density *seems* to be greater than that of the major planets is because the ball of the former being *luminous,* we see it directly, despite his tremendously deep and dense atmosphere. Were the ball to lose its brightness, we should see him as a dark disc whose diameter would appear much greater because it would then *include the thickness of his atmosphere;* and his density would suffer in the computation accordingly).

VELOCITY. Owing to two misconceptions hitherto prevailing, namely; (1) that dull stars are old, and hence presumptively massive, and (2) that proper motions are "inherent", Newtonians have been unable to formulate any rule whatsoever regarding stellar velocities. These latter, in their philosophy, are as capricious and arbitrary as the "inherent" motions themselves. The new principles which I submit are these:

(1) It follows mathematically from Newton's law of inverse squares and the law of the energy of motion, that if two bodies of different mass be conceived as occupying space alone, they will approach each other with velocities inversely proportional to the square roots of their respective masses. Dull stars, therefore, e. g., are consequently both small and quick moving.

2. Save in the cases of binary stars, where the circulatory relation is patent, current astronomy regards all star movements as rectilinear and dynamically independent. On the contrary, I regard all the stars as organically interrelated in the greater cosmos, much as the individual soldiers are constituent parts of a great army. Thus, the earth and moon form by themselves the simplest of all systems—a binary; the sun and his planets another, more complicated; the sun and one or more of his near neighbors a still higher system, whose extent and membership we have not yet been privileged to discover—and so on. You can see here that the minor members necessarily move more rapidly than the major, for the substantial reason that they have all the various *motions in cumulation.* It is therefore only to be expected that the smaller stars, in whatever relation they may find themselves, should, *caeteris paribus,* travel with greater celerity than the more cumbrous; as, in fact, they do. Star velocity, then, is a function of the mass, not directly, but *inversely* as the square roots.

BRIGHTNESS. Finally, as to the *intrinsic* brightness of stars. If it were possible to determine which is intrinsically the brightest of all stars, it would be equal to finding at the same time the very hottest and the very biggest as well—biggest not only in girth but in mass. Furthermore, it would be the least dense, and (less certainly) the most sluggish in movement. The reason for adding this last parenthesis is that *pivot-stars* (by which I mean such as, by reason of their relatively great size, preëmpt the central positions) have little motion besides that imposed by the direct action of their stellar resultant, whose strength varies, of course, in the different regions of the heavens, and may possibly attain, in exceptional instances, a high maximum.

"But", you may ask, "how are we to distinguish between those stars that are *intrinsically* the brightest and those that are brilliant only because of nearness?" The answer is twofold: (1) by the *color* of the given star, and (2) by its *spectrum;* which characteristics in all cases corroborate each other. The more refractory the spectrum (that is to say, the more involatile the elements it reveals) the brighter the star in itself. In choosing the monuments, therefore, for celestial surveying, care should be taken to select a series of Class A stars (which, according to my interpretation, are the very largest), whose color and spectra *both* are nearest alike. Of course the *visual* magnitudes of these stars, owing to their diverse distances, will vary widely, even though their *intrinsic* brightness, as I claim, is quite the same. It can readily be seen, then, that in this scale of differing apparent magnitudes based on a choice of stars *equally bright intrinsically and of the same order of size,* we have a most satisfactory and reliable means to gauge the stellar distances; and, secondly, inasmuch as these stars are by parity of reasoning the slowest-moving, we have at the same time reasonably stationary celestial pins from which to estimate the wanderings of stars less stable. This principle need not be limited to Class A stars, but can be applied whenever desired and convenient to a series of stars drawn from any other isochromatic spectral class.

It follows deductively from the premises that the bigger stars, being by hypothesis hotter for that reason, volatilize a correspondingly larger percentage of their component substances; thereby increasing the size of the inner chamber of gases relatively to the thickness of the shell for these reasons, namely: (1) by direct augmentation of the quantum of the gas at the expense of the shell, (2) by enhanced expansion of that gas due to the increased temperature, (3) by pushing the shell out that much farther, thereby enlarging the area over which the shell-substance must spread itself, and (4) by virtue of the circumstance that the weight of the shell, under the law of the inverse square, diminishes with its distance from the center, rendering easier its further uplifting. But let us now consider the effect of all this on the texture and conduct of the shell itself:

In the first place, the gradual distillation-out of the more volatile substances necessarily *simplifies its chemical constitution* and correspondingly affects the quality of the spectrum.

Secondly, the increasing predominance in the geysers of the more refractory materials which, as we all know, in their incandescent state are dazzlingly brilliant, naturally augments the luminosity of the star as a whole.

Thirdly, the hotter the shell the more plastic or fluid is it; hence the freer the ebullitions, the less liability to clogging, and the more multitudinous the geysers, whose pinnacles it is that cast off the radiance. This feature not only helps to account for *increased brilliancy of stars with growth,* but explains why the very bright stars are never found among the long period variables, save of course, those of the eclipsing variety.

Finally, the fact that the shell of a star, notwithstanding its increase in absolute thickness with the star's growth, declines relatively to the other stellar dimensions, cannot fail eventually to weaken the star's structural stability and to bring about its automatic bursting and dissolution into a nebula. Nebulæ thus evolved are obviously of enormous extent, not only because of the maximal size of their parent stars, but also because of the maximal pressure under which the central gases were confined and from under which they all the more violently escape. There is, then, an arbitrary limit imposed by Nature beyond which no star can grow, howsoever favorably it may be situated for further growth, and howsoever stout may be its armor against cometary missiles from without. Here, in this simple explanation, we have harmoniously coördinated the following important considerations: (1) How the greater nebulæ are formed; (2) Why stars, though differing greatly in mass, yet observe a certain order of size, like trees and animals; (3) Why there is not and can never be a great "central sun"; (4) The dispersive force by which the destructive centralizing tendency of gravitation is counteracted and the balance of Nature automatically maintained. Just how large a star may become is another matter. Even this problem, however, is susceptible of mathematical determination within reasonable approximation, though we cannot stop to deal with this complex problem now. In my opinion Doctor Campbell greatly overestimates the possibilities, when he says (*Stellar Motions*, p. 158) :—

> The parallax of [*Canopus*] can scarcely exceed .01 or .02 of a second as a maximum. We can scarcely doubt that *Canopus* is radiating certainly 1000 and perhaps 100,000 times as much light as the Sun. If the effective radiating power of its surface equals that of the Sun, the surface must be fully 1000 times as great as the Sun's. Its corresponding volume would be 31,000 solar volumes. Its mass must greatly exceed the Sun's mass, probably between 1000 and 30,000 fold.

When stars of very large size, and of precarious structure because of their relatively thin shell, are subject to the stress of an especially powerful stellar resultant of short stem (a condition which occurs when many stars are in close proximity), they are forced to rotate on their axes with extreme rapidity, enough so at times as to flatten them out sufficiently thin to cause their poles to coalesce, and so to bring into being two stars of smaller size. This phenomenon is called *star-fission* and, though rare, is well-authenticated by the observers. In the majority of cases, it appears, this unique feat of surgery, when Nature attempts it, turns out a success, the sundered ends are successfully sealed and cauterized, and the severance of the celestial Siamese twins becomes an accomplished fact. However, there is at least one case where a failure in this sort of cosmic chirurgery seems to have been scored and resulted in a *double-nebula* instead. Harking back to Darwin's tidal evolution theory, the reader may argue, as indeed Darwin and his adherents do, that since the fission of stars can and does take place, the earth might have flung off the moon. The cases, however, as the sincere reader will see on second thought, are not parallel at all. In this connection compare this interesting passage from Doctor Campbell's book, (p. 291):

> The two stars [Beta Lyræ] are enormous in size, but of very low density. They are so close together as to be almost in contact. The two bodies are in form approximately prolate ellipsoids, with their longer dimensions in the line joining the two bodies. The immediate cause of the variable brightness is due, in large part, to the eclipsing of one body by the other, but there are probably other factors entering to a minor degree, such as tidal ebb and flow, which must exist, as the orbit seems to be slightly eccentric.

## VARIABLE STARS

In a sense all stars may be said to be *Variable,* for all alike have explosive graduated shells. In the very large stars, however, the shells are much more homogeneous and much more fluid, so that the ebullient action is practically uniform. I am speaking now, not of eclipsing variables, whose changeableness is obviously due to the intervention of companion bodies, but of those whose flickering is due to a change that goes on in the star itself. In the previous chapter I have already given the reader my version of the true nature of sun-spots and the reasons for their periodicity, and he has only to apply the same principles to the analysis of particular cases and phases of star variation. In this engrossing study, however, two exceedingly important points must be ever borne in mind, namely; (1) that a very high percentage of variables are abnormals, and (2) that abnormal stars are invariably subnormals. By this I mean, that after the collapse of a star, whether by spontaneous eruption or by puncture, it for a time drops to the temperature of stars of lesser mass, and, secondly, that in this collapsed condition it is bound to exhibit changes in its light—especially *fitful* changes. For illustration, compare the similar behavior of a coal or wood fire. Let it, however, not be concluded that only *recently* collapsed stars are subject to these variations, for our own sun is now in a normal stage for a star of his size, yet his sun-spot cycle is certainly a true variation. Apropos of this subject, let me quote another passage from Doctor Campbell (*Stellar Motions*, p. 283):

> A study of the periods of variable stars brings out most curious relations. The periods clearly have preferences for certain lengths. There are a large number whose variations from maximum to minimum and back to maximum are completed in approximately one day, and many whose periods are half a day or less. As the period lengthens from one day, the number of variables decreases rapidly until we reach the few of eleven-day period. There are relatively very few variables with periods between 11 days and 110 days. Variable-star nature seems to abhor this interval. Beginning with 110 days, the number of variables increases rapidly, with increase of period, up to a maximum at 345 days; and the number of variables then decreases rapidly until we reach periods in length approximately 450 days. There are few with periods longer than 450 days, and our information concerning them or their periods is extremely meagre. It is of interest to note that *Omicron Ceti*, with average period 331 days, is but one of a great number which make up the maximum near 345 days.
>
> Long-period variable stars differ from short-period variables in important particulars. The former vary in brightness through a wide range, usually from three to eight visual magnitudes. Short periods, on the contrary, have small ranges of brightness, varying through 0.2 of a magnitude or less up to a maximum of 1½ magnitudes, with few exceptions. The long-period variables are all reddish in color, apparently indicating that the atmospheres of these stars are dense, absorbing the violet rays and transmitting the waves of longer length, or that we are dealing with low-temperature radiations. Short-period variables, on the contrary, are all yellow or white in color. Chandler has found that there exists a relation between the length of period and redness. To quote him: "The redness of variable stars is, in general, a function of the lengths of their periods of light variation. The redder the tint, the longer the period." Whether the conditions which produce redness are also the cause of long periods is an unsettled question. These long-period red variables do not conform to definite time schedules. Their maxima may precede or may follow prediction by a fortnight or a full month, but the average length of twenty-five consecutive periods will differ al-

most not at all from the average of the twenty-five preceding or following periods.

Of the reasonably bright short-period variables there are about 100 which pass from maximum to minimum and back to maximum within less than thirty days; nearly all of these, within ten days, and some of them within a few hours. In all these cases maxima and minima arrive on time, and the periods of most of them are known within a second. One cycle of change is almost exactly a duplicate of the preceding and following cycles.

The key to all changes and states of brightness in stars obviously lies in two things, namely; (1) in a close analysis and comparison of the pertinent spectra, and (2) in a systematic determination and tabulation of the luminosities of the various minerals (metals, more especially) at different temperatures. I note that some work along this latter line has already been attempted, but nearly all of it remains to do.

Entering into the matter is this feature also: Inasmuch as, according to my version, the light of a star comes to us, not from its level surface but from its ascending geysers, it follows that *the swifter the velocity with which these rise toward us the higher radial velocity should the star's spectrum indicate.* Furthermore, where the star is variable it should appear at its maximum brightness when its deeper-seated, more refractory, substances are ebulliated; which is to say, when the geysers are thrown up highest and fastest. This reasonable deduction is curiously confirmed by the action of the classes of variables known as *Cepheids* and *Geminids;* speaking of which Doctor Campbell says (p. 306):

> Interpreted, we have the astonishing result that every star investigated has its maximum brilliancy at or very near the time of greatest velocity of approach toward the solar system, and the minimum brilliancy at or very near the time when the bright star in the system has its maximum velocity of recession from the solar system. *These are keys which give promise of unlocking many secrets of the Cepheids and Geminids. What can be more remarkable than that variable stars of this class should be at their brightest when they are moving rapidly toward the observer and at their faintest when they are moving rapidly away from him?*

## THE NEBULAE

Nebulæ are at once the ghosts of departed stars and the corpora of other stars yet to be born. They are not primordial, but transitional forms; the first star preceded the first nebula. They differ fundamentally from the original cosmic dust in having passed through the stellar crucible and consequently undergone considerable chemical rearrangement and combination. Furthermore, although much of it may have been lost in the cataclysms that gave them birth, they retain in their nebulous condition some remnant of the *motion* possessed by them as member stars of the systems that have vanished.

Owing to their explosive origin, nebulæ are naturally capricious and nondescript in form, and there is little to be learned from their *incipient* shapes. Their sizes, however, vary so widely as to demand categorical explanation. I have already recounted at length the production of the smaller nebulæ by the spontaneous explosion or puncturing of stars, and of large nebulæ by the bursting of maximum-sized stars from sheer over-growth. All of these, however, might perhaps result in rather too simple and regular forms to suit *every* nebular outline, and there might remain also a doubt as to whether the destruction of even the biggest star would commensurate with the size of the biggest nebula. To account for the *extraordinary* cases, then, such as Eta Argus or Orion, for example, I suggest that the explosion of some monster star in the near vicinity (as stellar distances go) of a cluster of other large stars might cause the puncture of several more, each succeeding explosion, moreover, creating a new center of destruction. In this way *any* size or irregularity of nebula that the heavens may present to the telescopic eye can be accounted for.

No sooner is the nebula spread out—nay, while it is yet in the very act of spreading—it begins to react to the subtle but all-powerful influence of its stellar resultant and to struggle within and upon itself for gravitational equilibrium. This, of course, is a tediously slow process, for the reason that the projectile momenta of the ejected material require to be mastered and disciplined. However, fortunately for science, we do not need to wait to see one particular case through before arriving at conclusions, since there are many thousands of these curious objects in the sky in different stages of deployment and evolution, so that by putting two and two together we can write the individual histories of all. Hitherto the teaching has been, that the moment of momentum of any segregated system cannot change, and that a nebula is to all intents and purposes a *system* and amenable to the rule. But that here, again, fact and theory do not gibe, note these words of Kapetyn:

> The phenomenon of the increase of velocity with the evolutional stage of the stars must give rise to speculation as to its cause. The observational results contained in our table naturally lead us to conclude that the matter from which the stars originate must have little or no velocity. How is this possible under the influence of the combined attraction of the rest of the system? *Is it not as if gravitation had no effect on the cosmical matter in its primordial state?* If this be so, as soon as matter changes from this state to another in which gravity begins to act, or to act freely, motion will arise, and it is evident that, as a rule, the motion must be accelerated, at least during immense periods, so that the longer the period lapsed since the birth of the stars the greater must be their average velocity.

It would take us too far afield to enter into a detailed discussion of the numerous capricious forms of nebulæ, caprices that the very nature of their origin as hereinbefore set forth sufficiently accounts for; and we shall therefore confine this inquiry to the far more important consideration of the origin and significance of *spiral* nebulæ, which obviously involve structural dynamics of basic character. These peculiar nebulæ so far outnumber all others put together that the inference is unescapable that they are the *advanced* stages of a cosmic process by which *all* nebulæ are being molded. They are simply systems of planetary bodies enshrouded in star-dust expelled by the explosion of their central sun or suns, which they are gradually redding up by their gravitational suction while regularly rounding their orbits. To visualize such a spiral nebula you need only imagine our sun to explode profoundly, and then picture in your mind's eye what convolutions should take place in the nebula by the action of the planets. The exaggerated sizes predicated of some of the nebulæ are no hindrance to Nature's disciplinary powers. Be a nebula as large as it may, *it still has its master stellar resultant, it still remains subservient to the inexorable law of equilibrium, the law of the balance-arm, Kepler's laws, the law of the logarithmic spiral, the law of gravitation—all one and the same in essence.* By way of exemplifying these remarks let me cull still another extract from Professor Eddington's book (p. 241):

> It is generally believed that the spirals predominate enormously over the other classes of nebulæ; and, as the whole number of nebulæ bright enough to be photographed has been estimated by E. A. Fath at 160,000, they must form a very numerous class of objects. They are seen by us at all inclinations, some, like the Whirlpool Nebula, in full front view, whilst others are edge-on to us and appear as little more than a narrow line. An example of the latter kind is also illustrated in Plate IV. In all cases, where it is possible to discriminate the details, the spiral is seen to be double-branched, the two arms leaving the nucleus at opposite points and coiling around in the same sense. From the researches of E. v. d. Pahlen, it appears that the standard form is a logarithmic spiral. The arms, however, often present irregularities, and numerous knots and variations of brightness occur. Unlike the planetary and extended nebulæ the spectrum shows a strong continuous background; bright lines and bands are believed to occur, at least in the Great Andromeda Nebula; but they are of the character of those found in some of the early type stars, and are distinct from the emission lines of the gaseous nebulæ.
>
> The distribution of spiral nebulæ presents one quite unique feature; they actually shun the galactic regions and preponderate in the neighborhood of the galactic poles. The north galactic pole seems to be a more favoured region than the south. This avoidance of the Milky Way is not absolute; but it represents a very strong tendency.
>
> In the days before the spectroscope had enabled us to discriminate between different kinds of nebulæ, when all classes were looked upon as unresolved star-clusters, the opinion was widely held that these nebulæ were "island universes", separated from our own stellar system by a vast empty space. It is now known that the irregular gaseous nebulæ, such as that of Orion, are intimately related with the stars, and belong to our own sys-

tem; but the hypothesis has recently been revived so far as regards the spiral nebulæ. Although the same term "nebula" is used to denote the three classes—irregular, planetary and spiral—we must not be misled into supposing that there is any close relation between these objects. All the evidence points to a wide distinction between them. We have no reason to believe that the arguments which convince us that the irregular and planetary nebulæ are within the stellar system apply to the spirals.

It must be admitted that direct evidence is entirely lacking as to whether these bodies are within or without the stellar system. Their distribution, so different from that of all other objects, may be considered to show that they have no unity with the rest; but there are other bodies, the stars of Type M for instance, which remain indifferent to galactic influence. Indeed, the mere fact that spiral nebulæ shun the galaxy may indicate that they are influenced by it. The alternative view is that, lying altogether outside our system, those that happen to be in low galactic latitudes are blotted out by great tracts of absorbing matter similar to those which form the dark spaces of the Milky Way.

If the spiral nebulæ are within the stellar system, we have no notion what their nature may be. That hypothesis leads to a full stop. It is true that according to one theory the solar system was evolved from a spiral nebula, but the term is here used only by a remote analogy with such objects as those depicted in the Plate. The spirals to which we are referring are, at any rate, too vast to give birth to a solar system, nor could they arise from the disruptive approach of two stars; we must at least credit them as capable of generating a star cluster. * * *

The two arms of the spiral have an interesting meaning for us in connection with stellar movements. The form of the arms—a logarithmic spiral—has not as yet given any clue to the dynamics of the spiral nebulæ. But though we do not understand the cause, we see that there is a widespread law compelling matter to flow in these forms.

## NEBULA- AND STAR SPECTRA

The manner of the formation of nebulæ, as just described, seems to me to supply the key to the peculiarities of their spectra. For the freshly liberated gases will be expelled to unequal distances, and the lighter elements the farther. The outer envelopes of the nebula should therefore consist largely of hydrogen and similar gases; and if these envelopes be sufficiently dense so as to be opaque to the light of the other incandescent elements ranged behind them, the predominance of such lines in celestial spectra should cease to surprise. Given sufficient allowance of time in which to act, gravitation would of itself dispose the elements in the same order, that is, the lighter on the outside.

The so-called "green" nebulæ are therefore younger than the "white", and, by the same token, naturally larger, from not having been condensed by long exposure to the cold of space. Their youthfulness is further attested by the fact that less than five per cent of nebulæ are green, a circumstance which opens interesting avenues to the determination of the relative ages of nebulæ in general. The Milky Way, being the densest portion of the sidereal system, is naturally richest in all sorts of nebulæ, but particularly in the percentage of those of this green, or ultra-gaseous, type. The difference between the various classes of nebulæ is therefore accidental rather than fundamental or generic. The manner of their formation (that is, by explosion) naturally arrests and masks such proper motions as their parent star may have had just prior to the catastrophe, so that the new-born nebula is obliged to "find itself", as it were, and to acquire its new motions by a protracted process of gravitational acceleration. As the "dust from the explosion" settles and clears, the nuclei, which were always there, but only hidden from our sight, loom gradually into view, and then we perceive a spiral nebula, evenly poised like a giant pinwheel on a center, recrudescing into a new cycle of existence.

The double spectra of stars are never visible except where two bright stars are knowingly examined at one time, as in the case of binaries, or where there is evidence of some special eruption in progress on the body under examination. In the latter case the confusion of spectra is due, I opine, to the violent geyser-like ejection of gas from one section, while the other part of the surface remains normal. A suggestive illustration of this may be seen in certain comets, which now and again exhibit luminous spurs, or jets, directed toward the sun. Moreover, geyers that rise must concurrently fall back by the action of gravity, thereby producing double spectra, indicating both *plus* and *minus* radial motions.

### THE RINGS OF SATURN

In the large sense, all celestial bodies may fairly be included under the generic name of stars, for even the smallest of them may conceivably be the embryo of a *Canopus* or *Arcturus* gestating in the fertile womb of Time. Such enormous planets as Jupiter and Saturn are not very distant approximations to lucid stars, as may be inferred from the phenomena of the "great red spot" characterizing the former, and the "rings" that render Saturn so gloriously unique among telescopic objects. My explanation of these wonderful appendages is that Saturn has, in comparatively recent times—probably as late as the Neolithic age—been profoundly shattered by an explosion, from causes such as I have outlined, thereby giving birth to a genuine, if relatively minute, nebula, which, under the tutelage of the Prime Resultant subsequently took on permanent vortical motion.

## XI

# GRAVISTATIC HEAT

IN earlier chapters we have seen how grossly Newtonians have been undervaluing the functions of the principle of universal gravitation in the domain of planetary and stellar motions. They have employed it negatively rather than positively; destructively rather than constructively; as a clog, a brake, a restraint, instead of as a never-failing well of motive power. They accept the so-called rectilinear motions as gifts out of the occult, not in the single particular of momentum or velocity, but in those of adaptation and direction as well; and they employ gravity merely to lasso and tether the self-flying stars and planets. In the same way they postulate the rotations of the sun and planets as ultimate facts, or, at least, as conditions inherited from prior motions which themselves were self-existent; and then they invent an explanation of tides in which the role of gravity is to retard those rotations and eventually to bring them to a standstill.

Furthermore, we have seen how, following out this medieval style of speculation, and perceiving, but misinterpreting, the exquisite balancing of our system from day to day and year to year, they invented another abstraction, namely, the law of conservation of moment of momentum, which is conceived to control celestial motions, not through the ordinary channels of physical cause and effect, but by some sort of teleological ordination or oversight vested in abstract energy as matter's master and mentor. But this preposterous assumption fails to correlate the phenomenon of the moon's acceleration, and the whole subject is consequently as awry as ever.

It is this paganish dogma of conservation of moments that constitutes the chief pillar of the so-called doctrine of

## CONSERVATION OF ENERGY

*"The quantum of energy within any isolated system is absolutely invariable in amount".*

I peremptorily challenge this teaching as a gross libel on Nature and a wanton perversion of the plain facts. Laymen, in general, seem to have imbibed the impression that in this generalization science has struck rock-bottom, and that it constitutes a virtual guarantee of the perpetuity of the universe and a solid foundation upon which to anchor the science of physics for all time to come. No conclusion could be farther from the truth. The classical English work on this theme is that of Prof. Balfour Stewart, and was first published in the year 1870. This is how he concludes:

> We are led to look to a beginning in which the particles of matter were in a diffuse chaotic state, but endowed with the power of gravitation, and we are led to look to an end in which the whole universe will be one equally heated inert mass, and from which everything like life or motion or beauty will have utterly gone away.

Although you and I can have no personal concern in the ultimate fate of the physical universe so far as our present existence is concerned, yet I imagine that we all experience a greater or less philosophical interest in the academic question as to whether the universe had a beginning and whether it shall ever have an end. For my part, the doctrine that the universe is a vast machine in the act of running down from an original state of wound-up-ness to a futile and inglorious *fiasco,* is little short of blasphemy. Nor do I believe that I am alone in this sentiment. The perseverance with which all ranks of scientists have sought for generations to account for the well-established longevity of the sun leads me to believe that they also sense this conclusion. In a word, the doctrine of conservation is *a priori* false.

The commonest definition of *energy* is, "The power that can or does cause a physical change." In their efforts to visualize the operation of this supposititious principle of conservation in the conduct of nature, it has become usual with scientists to liken the imaginary original supply of it to a great reservoir of water advantageously situated on the summit of a high mountain whence it descends by degrees, circulating and meandering through material nature, appearing now in the guise of motion, then as heat, again as magnetism, anon as light, once more as heat, and so on back and forth, to and fro, indiscriminately, until the final end. This descent from higher to lower potential is spoken of as the "degradation of energy", and the end of the whole process is pictured as a dead sea below the level of which energy can drop no further, and where absolute stagnation will prevail. They have given a name to this figurative sea, namely, "Wärmetod", being the German for "heat-death". For *all* energy is conceived by them to pass eventually into the single form of heat. Indeed, the relation of heat to motion is supposed to be so well understood and established that their equivalents have even been reduced to tables to make dynamical computations easy. The study itself is called *Thermodynamics,* and these are its two so-called "laws":

> 1. *For every unit of energy of any kind that disappears a unit of another kind appears.*
>
> 2. *Heat can only pass from a warmer to a colder body.*

You will here perceive that between the original strategic position of the store of energy while in the reservoir and its final inert condition in the sea of Wärmetod, there exists an abysmal distinction. In the latter state, all kinds of energy having become resolved into heat alone and all bodies having, by construction, arrived at the *same* neutral level of temperature, it is apparent that Nature has betrayed herself into a stalemate. Though the *sum* of energy may still exist, in contemplation of theory, it is, by the same theory, recognized as all foredoomed one day to become forever inert and useless. Conservationists themselves distinguish between kinds of energy by calling the higher levels or potentials, as contrasted with those of lower grade, *available,* and those of the lower, *unavailable.* That is to say, all energy except that at the very foot of the course is held to be at once available and unavailable—available as to the lower part of the runway, unavailable as to its upper reaches. As the descent is forever going on, they tell us, the quantum of unavailable energy is constantly increasing at the expense of the available. Here, then, in this general sense, as in the special case of gravitation, *we are taught that the primordial, the positive, the motive forces of the universe of matter are losing their virtue and that nature is in an irremediable state of decay.*

The extremes to which scientists have shown themselves willing to go in the pursuit of this execrable doctrine are all but incredible, extending even so far as to the open and unreserved repudiation of the principle of universal gravitation itself! Let me ask the kind reader to turn now again to the passage previously quoted from Prof. Soddy (p. 4, *ante*) before proceeding further.

In these lines Prof. Soddy talks as impassionedly as if he had a grievance against Gravitation for having too long imposed on scientists as a real thing instead of a mere assemblage of letters. In Mr. Soddy's gospel, *position* and *power* are interchangeable terms, while gravity itself is a low impostor that should be excluded from the polite purlieus of scientific language. But if position, *as such,* is power, then the energy positioned in Wärmetod *is not properly characterizable as energy at all;* for how can that be energy which can never in the future by any possibility do work; or how can position continue to be energy when, even in this technical sense, *it has ceased to be?* To talk of energy as becoming *unavailable for all time* is to assert its becoming non-existent absolutely.

There are but three possible hypotheses by which the relation of matter and energy may be explained, namely; first, by construing them as *identical;* secondly, by regarding them as *separate entities,* and, thirdly, by supposing energy to be a *state* of matter, or, in other words, that it is only, *the way matter has of manifesting itself to our senses.* Of these hypotheses the first was known as the theory of *Phlogiston* and prevailed all through the lifetime of Newton; the second is that now universally taught in the schools, and the third is my own.

In the narrow limits of current theory the marvelous force of gravitation cannot be made to fit, so the doctrinaires are little by little sophistrizing it altogether out of existence. In their philosophy gravitation is a tether, a brake, a clog. In the field of planetary motions they have even cast doubt upon the actuality of central attractions, because they cannot reconcile it with the secular acceleration of the moon. In thermodynamics they have degraded it into a mere *accident of situation.* At best, they treat it as a reservoir of power soon drained, instead of as the never-failing well it really is. They say it is not creative; that whatever it is, it will all eventually be converted into heat and perish in stagnation and triviality.

In my philosophy, on the contrary, gravitation is the marvel of all marvels, the immortal fecund mother of all other so-called forces in nature. When gravitation first entered into matter, it made every part of it a permanent magnet, unchangeable, imperishable, and obedient to an unswerving law. Whether a given mass be hot or cold, gaseous, solid or liquid, separate or in combination, its inherent power to attract and be attracted remains forever identically the same. The power of gravitation cannot be crowded into matter, nor can it be abstracted from it—like the widow's cruse, the world of matter preserves its fulness. Gravitation needs not to be fed, nor rested, nor fostered. Every instant it wells up afresh. The attraction that the earth exerts today upon the moon, the sun upon his planets, the stars upon each other, is not the same that will be employed to-morrow or next day;

the supply for the future, Nature will evolve as it is required. The attraction of gravitation exercised to-day had no existence yesterday, whether as such, or as heat, or as electricity, or as any other entity. Though always flowing afresh, its supply is not being in the least depleted, nor is Nature being despoiled of anything beyond. Further than this, the force of gravitation is multiple. The earth, for example, attracts the sun no more and no less than it would were the moon out of the way, yet it attracts that body too, to say nothing of all the other celestial bodies—each of them with precisely the same strength as though only the two existed. Again, the power of gravitation makes itself felt over the abysses of space *instantly,* not, as in the case even of light itself, after a space of seconds or years. Finally, it cannot be eclipsed, as by the interposition of the earth between the sun and the moon. Ponder this marvel! Force emanating out of nothing, uniform, all pervading, instantaneous in action, eternal,—the Hercules condemned forever to perform the labors of the universe; to hold and draw the planets in their orbits; to turn them round their axes; to stoke the suns; to heap the tides; to scatter the rains; yes, even to point the mariner's compass with the magnetism of tidal friction! An unthinking, rigidly-conditioned force, yet not ending in monotony or ruin, as modern science teaches it must, but emerging in order, automatism, perpetuity, and kaleidoscopic change! Has current science made the most of this amazing energy?

Having cast about so long, yet vainly, for an explanation of the persistency of the solar heat, why not patiently consider the merits of *gravitation* as a last resort? Behold the sun tempestuously ebullient after a service of more than a hundred thousand times the span of human history, when, as Newcomb has said, were it an ordinary body it would have cooled off in a trifle of 4,000 years. Behold Jupiter and Saturn, elder brothers of our earth, that, according to the doctrinaires, were set out to cool ten million centuries ago in the absolute zero of space, yet even they, mere dwarfs as compared to the sun, are still glowing with fervid heat. Behold the starry host, whose genesis lies in darkest shadow; yet in the present we see them brilliant and serene without a hint of senility about them. Surely there is a principle of vitality about this universe of ours that the wise have overlooked!

In the commercial field scientists have for years been seeking to devise methods and means for economizing mechanical power. To some extent they have succeeded, but they have invariably discovered that, for all their skill and care, every successive step in the processes of conversion,—from coal to heat, from heat to steam, from steam to mechanical motion, from this motion into electricity, etc.,—there is a *leakage* which defies fathoming. Yet in spite of their failure to trace these losses and to demonstrate quantitatively the verity of the doctrine of conservation, they ignore these lessons entirely and cling unreasoningly to this their pet delusion. They seem to proceed on the assumption that phenomena must adapt themselves to theory, not theory to the phenomena. Now, a little reflection ought to convince all that in inanimate nature these transformations, which are continually and uninterruptedly occuring, are likewise amenable to just such leakages as these, and that were the doctrine indeed true, the descent from high potential to the lowest should run its course so fast as scarcely to last a year. Given a mountain reservoir with the sluices left wide open, the rush for the sea would be short, swift and ruinous; given a highland brook continuously replenished by the rains, the flow of power will be equable and perennial. *The mills of Nature are not driven by an avalanche, but by steady evolvement of power.*

Our doctrinaires tell us that there is no such thing as creative energy in nature. They construe the operation of an infinity of years as if it were but a momentary act. They tell us that the earth attracts the moon and holds her to her course, but they fail to recognize that the gravitational power which the earth will bring to bear during the next turn of the satellite *does not yet exist, but must spring into existence during the ensuing thirty days*. Where, I demand, shall it come from? From an *accumulated* store of energy? If so, how comes it that this store has not already exhausted itself in the eons past? How comes it that there has not been during astronomical history even the slightest evidence of the depletion of this strange power? It ought to be plain to every thinking mind that gravitation is creative in its nature, creative because *matter is dynamical in essence.*

By some strange quirk the scientists have excogitated the lunacy that when a weight comes to rest upon the ground, gravity is done for, that its energy ceases. They reason thus because they have trained themselves to confound the idea of *space* with the *antithetical* idea of *power;* in fact they actually *identify* these two diverse things in their processes of ratiocination. Let me ask, what is it that moves the train—the locomotive, or the track? The locomotive, of course. Now what is it that causes the apple to fall from the tree—gravity, or the free space between the twig and the ground? Gravity, of course. Does gravity, then, act on the apple only while the latter is in the state of falling, or did it not also pull on it while it was yet on the tree, and will it not continue to pull upon it forever, after it has found a permanent resting place on the earth? I expect you to answer in the affirmative. We all agree, then, I trust, that the effective cause for the fall that has taken place is not so many feet of bare space, but *gravity,* be gravity what it may. Now gravity has this peculiar property, that it *waxes* with exertion, not wanes; that is to say, its force increases indefinitely with the shortening of the distance. The attraction upon the apple when lying on the ground is therefore stronger than when it still clung to the tree, stronger than when it was in the act of falling, *stronger than at any time in the past.* Yet the Conservationists say, in effect:

"Given this force known to be capable of producing a specific mechanical result, then if the same be increased to a maximum and so maintained indefinitely, its effects will altogether cease and disappear, nor will any other sort of mechanical consequences appear in their place!"

Furthermore, Conservationists in their blind zeal confuse the element of *force* with the element of *velocity*, and claim, for example, that a mountain resting on its base produces no mechanical effect, for the bare reason that it is *not in motion.* The formula by which they thus conjure is this:

$$E = \frac{1}{2} MV^2$$

in which M is the mass, V the velocity, and E the energy. Obviously, if there be no movement, V becomes zero, and the substitution of this value in the equation, *be the mass as big as it may,* will reduce the energy to nothing. Nobody denies that gravitation continues to go on drawing; but we are told that, once settled on a permanent base, the weight of an object, whether a mole-hill or a mountain, counts for nought.

Scientists, furthermore, divide *available* energy into two sorts—potential, or that which stands in reserve against future use, and kinetic, or that which is in the act of doing work, or being converted. In order to get the scientific view authoritatively before the reader let me present this extract from the illuminating essay on *Energy* by Professor John Gall, formerly of Canning College, Lucknow:

> A reservoir of water situated on the summit of a hill is more valuable than the same body of water at a low level. This is owing to the store of energy which it possesses in virtue of its position; and as the water descends this energy may be turned to good account in driving machinery. If the reservoir is situated at a lower level than the machinery the water becomes useless as a motive power. A cross-bow when bent, the main-spring of a watch coiled up, a labourer primed for work with a sufficient supply of food, are instances where the energy is due to position.
>
> We have already seen that when a body is projected vertically upwards it possesses kinetic energy in virtue of its motion. As it ascends its velocity and consequently its kinetic energy decreases, but at every point of its ascent it has gained a quantity of potential energy equivalent to the kinetic energy lost, and when the body ceases to rise, the kinetic energy vanishes and the energy becomes wholly potential. In every position of the body the relation expressed by the following equality always holds good:—
>
> $$\text{Kinetic Energy} + \text{Potential Energy} = \text{A constant.}$$

When the projected body begins to ascend, its energy is entirely kinetic, because while at the surface of the earth the potential energy of a heavy body is zero. On reaching its highest point the kinetic energy has vanished, and potential energy appears in its place. As the body descends, the energy is again reconverted from potential to kinetic. In positions intermediate between the highest and lowest points the energy consists partly of one kind and partly of the other, and as the body moves from one point to another, a constant transformation of one form of energy into the other is constantly taking place, subject always to the condition that the sum of the two remain constant.

You will perceive from this statement that *clearance* for fall, not the *power* that causes the fall, is looked upon as the vital factor. Is not this *prima facie* absurd? Gravity, it is admitted, pulls the object downward *before* the fall began, *during* the fall, and *after* the fall, but the Conservationists deny to its operation the production of any effect *save for the short span of the fall and the brief moment of the settling of the object after.* It is a clear case of mistaking identities. Proceeding on this manifestly false tack, our doctrinaires have in all their theorizing assumed the force of gravity to be innocuous and sterile *just when, under the letter and spirit of the law of the inverse square, it rises to its maximum!* Let us pursue this train of reflection further:

Knowing, as we cannot fail of doing, that it is in the nature of gravity to be sleeplessly active in the control and movement of stars and systems, does it not appeal to your reason that it should be equally persistent and cosmically productive in situations where molar movement is obstructed? Is it good sense to say, or to suppose, that by bringing power and matter in great quantity together, there must ensue an end to activity and that Nature thus stupidly engineers her own defeat? If gravitation can whirl about stellar masses with ease and expedition, do you see no logical reason for assuming *a priori* that, balked in producing *molar* movements, it may under the wise management of Nature be diverted to the no less vital task of stimulating *molecular* excitation and thereby generating heat?

Behold there an enormous mountain of a billion-tons weight. Put in its place an enclosed cone of *papier maché* of like dimensions; what effect, if any, should such substitution exert upon the supporting shelf? According to the interpretation of the Conservationists, there would be no effect whatsoever experienced by the shelf, except, possibly that its natural elasticity might slightly raise its level with the removal of the weight. The real mountain, say they, produces no thermal results so long as it maintains its level and sinks no lower, for it is not the *power* that counts but the *space* through which that power acts! It is upon this particular dictum that the Helmholtzian theory of the source of solar heat is founded, and that the future degradation of the luminous stars into cold, dark clinkers is predicated. In thus failing to distinguish between the dynamical potentialities of diversified weights and treating them all as precisely equal, scientists have, in my opinion, been guilty of a grave and incalculably costly blunder.

The spectroscope informs us that a rare few of the nebulæ are self-luminous—they must therefore be hot. How came they so? What more natural than to attribute the phenomenon to the grinding and crushing of the inner substances by their parent stars, not into powder, simply, but into molecules, atoms, electrons—as fine as you will, even to the point of torpedoing themselves into these great glowing mists?

In a previous chapter I pointed out the property of substances in general to explode by percussion or by sheer pressure; leaving in some minds, perhaps, a lurking doubt as to whether the principle of the critical point of gases can come into play unless a very high temperature be first provided. My contention here is, that, even were the cosmic body composed solely of solid, refractory materials that had attained a condition of stable compactness, the process of the generation of heat would continuously go on forever. In my conception, *hotness is the natural state of matter when under extreme pressure.* Compression is neither more nor less than *perpetual impact.* Let me make this matter certain:

If a pound-weight were to alight on your toes by falling from a height of six feet or so, it would cause you a moment of sharp agony; but supposing no bones to be fractured, the pain would be soon over. Suppose, again, that you were to allow the weight to drop from precisely the same height as before, but this time on the pan of a spring balance (you noting at the same moment the force of the impact as registered on the scale) and that you should then procure a boulder of this greater weight and merely *rest* it on your toes—would you not suffer in this case, not merely for a passing instant, but for *as long as the boulder remained in position?* Most certainly! But the Conservationists, were they to argue consistently with their pet dogma, should say that the boulder would pain you only in its first placement, when it was yet in motion; but that afterward, when it had become motionless, it could not hurt any longer, because then it would have no velocity and consequently possess no energy, whether for paining or for generating heat!

Now, while it is quite true that matter does not sense pain as humans do, yet it ( or its molecules) experiences in a state of compression certain irritations analogous to pain, just as it does when struck a blow. Compression, by forcing the molecules closer together, excites them to reaction, multiplies their collisions, and produces the condition we call heat. Though our mountain may no longer be sinking, yet as long as it remains superposed on its shelf, its basal strata will endure constant strain and develope a perennial supply of warmth, which, despite the natural cooling of the surface, will maintain the average temperature of the mass above that of its surroundings until the end of time. To some minds long accustomed to think otherwise, this statement may sound paradoxical, but the discovery of radium a score of years ago should serve as a lesson to them not to be too skeptical. The phenomena of Nature loudly proclaim its truth—the boiling sun, the lucid stars, the volcanic earth, the fervid Jupiter, Saturn, Uranus and Neptune—or do they not?

Static pressure, I repeat, or, more specifically, *gravistatic* pressure, *is a perpetual generator of cosmic heat* and makes for the permanency of the physical universe as we now behold it. Collisions and impacts, on the contrary, breathe of the accidental, the transitory, the insufficient. The tacks that draftsmen use may easily be driven into the board by merely pressing the thumb upon them, but they can just as well be driven in with blows of a hammer. Once driven home, you may either continue the pressing or the pounding, but the tack goes, and can go, no farther. Science says this surplus *pressure* is *not* conserved, but that the excess *blows are.* I take issue with this narrow interpretation and submit the following reasons for your consideration:

The force of a hammer blow may be ascertained in terms of dead weight by merely letting fall on the pan of a spring scale and noting the poundage it registers. With such blows as this you may drive in a stake, or beat an anvil, or do many other things you might have in mind to do. If you cared to, you would not need to drive in the stake with the hammer at all, but you could hunt up a boulder exactly the weight of the hammer-blow as indicated on the scale, and this boulder, if merely rested on the top of the stake ought to press it into the ground quite as surely. If instead of driving in the stake, you chose to beat the anvil, you will not displace the latter, but you will *heat* it. Now, if you please, put the hammer aside and bring the boulder and *lay it* on the anvil and you will find that the boulder will warm the anvil as much as did the hammer-blows—and continuously. And why should this not be so? For how, I pray, is the anvil going to distinguish between a rapid succession of such *blows, divided by no interval,* and *absolute continuity* of the bearing weight? It is no more necessary for gravitation to go the roundabout way of first causing a fall in order to bring about the impact as a means of producing heat than it was for Charles Lamb's Chinese to fashion the fagots *into a hut* before starting the blaze for the roasting of the pig.

It is a customary thing in arguing for the doctrine of the conservation of energy to cite the illustration of raising a dumb-bell and directly letting it drop to the ground, and confining the attention to this simple case. It is explained, that in elevating the bell the lifter expends precisely the same number of units of muscular energy which the bell will develop in thermal units on being let go and striking the ground. "Muscular units expended, are compensated by positional units gained, and positional units lost, in their turn, are compensated by thermal units gained; and so on." *But suppose the bell is too heavy for you to so much as budge?*

Ah, that is a question which you are supposed to be polite enough never to ask. It seems as plain as can be that when you lift the dumb-bell, you use up a certain amount of muscular energy; but it seems just as evident, too, does it not, that when you pull and pull on an iron stanchion, or try to lift a heavy rail, without effecting the slightest movement in either, you are quite as certainly expending muscular energy? In the case of the dumb-bell our good friends tell us these units of muscular energy are replaced in the shape of kinetic energy by the fall of the bell, thus balancing the dynamical ledger; but they do not volunteer as to how they are compensated in the *second* instance.

Doubtless you have seen a team of horses straining to overcome a rise in the road and being lashed mercilessly by a brutal driver. Ten minutes pass, perhaps, with no progress made, and the mired wheels stick fast. Had all gone well and the hill been surmounted, we should be told the old fable of energy compensations; but not so in this case. These Conservationists know when ignorance is bliss, silence golden, and discretion the better part of valor. Possibly, too, you may have seen a horse bending every effort to hoist a trio of bales tied to a pulley; half way up something goes wrong, the horse pulls as hard as ever, but the load refuses to rise. What sustains the load thus in mid-air? Cut the traces and you will see that it is the *pull* of the animal. In fine, these examples demonstrate that energy is often expended, lost, destroyed *in merely maintaining, or not altering, the status.*

Again, suppose, in passing along a walk flanking the precipitous side of a hill, you should notice a loose stone just above your head menacing the safety of passers-by and that you should reach up and gently lower the stone to the level of the walk. In this case, by lowering the stone slowly and by laying it softly on the ground you will have done two things; (1) destroyed so many units of your muscular energy, and (2) destroyed about an equal number of the potential units of the stone—but without, however, adding a single unit of any other sort of energy in substitution. Or, by way of variation, suppose you were to lift the dumb-bell to arm's length, but instead of dropping it or lowering it at once you were to keep holding it aloft until you grew weary, and then to lower it again with the utmost slowness,—could any Stewart or Soddy convince you that the energy units gained by this stunt exactly counterbalance the muscular effort you have put forth?

Energy being, according to my conception, an act or *manifestation of matter* itself instead of an intangible something acting through matter, it follows that these acts or manifestations are indefinitely repetitive in character. As long as matter *exists it* will *manifest* itself. Energy is *not* matter, nor matter energy, but MATTER IS ENERGETIC.

To illustrate: It is Newton himself who is entitled to the credit of originating the conception that the earth's gravity holds the moon in perpetual leash, and that were this power to run out or forget to act, even for a second, the moon would fly off into space. What, then, can be plainer than that the unique force of gravitation is *creative,* that it evolves afresh in every new instant of time, and that they who deny the existence of such a source of vitality and recuperation in Nature simply misstate the fact? But Newton confined his attention to only one side of the shield; he considered only the matter of centripetal force, but the centrifugal he left to teleological speculations. Now, a *creative* force on one side serving as the "action" can be evenly counterbalanced on the other only by a like *creative* force to serve as the "reaction." The centrifugal force, *too,* then, must evolve freshly out of Nature, and should *it* run out instead of the central attraction, the solar system would promptly collapse and crash together. In fine, in order to keep the planets gyrating around the sun—that is to say, merely to make them *change their places,* without at the same time either adding to or taking away any of their so-called "energy of position"—demands the constant exercise of those two enormous sources of creative energy, namely, the sun's gravity, and the stellar resultant. The present teaching is, that to start a body and to stop it require the putting forth of equal amounts of energy, but that the transportation *in between* requires none. I maintain, in opposition, that change of place of any physical body, even along the level, involves a positive destruction of units of energy (using this term in the conventional sense). In brief, the activities of nature—of translation as well as of warmth—literally consume energy, and to offset this loss, I say, nature must and does *evolve* it.

In order to show the reader how near scientists have already come to laying hold upon these truths, had it not been for their obscuration by the doctrine of conservation, let me quote two passages from standard works. The first of these is taken from Ganot's *Physics,* Art. 465, (Ed. of 1877, retained in that of 1910).

> If a body be so compressed that its density is increased, its temperature rises according as the volume diminishes. Joule has verified this in the case of water and of oil which were exposed to pressures of 15 to 25 atmosphers. In the case of water at 1.2° C., increase of pressure caused lowering of temperature, a result which agrees with the fact that water contracts by heat at this temperature. Similarly, when weights are *laid* on metallic pillars, *heat is evolved, and absorbed when they are removed.*

The second of the extracts is to be found in Professor Richard A. Proctor's *Our Place Among Infinities* (pp. 117, 118):

> At exceedingly high temperature, much greater pressure, and therefore much greater density, can be attained without liquefaction or solidification. And in considering the effect of pressure on the materials of a solid globe, we must not fall into the mistake

of supposing that the strength of such solid materials can protect its substance from compression and its effects. We must extend our conceptions beyond what is familiar to us. We know that any ordinary mass of some strong, heavy solid—as iron, copper, or gold—is not affected by its own weight so as to change in structure to an appreciable extent. The substance of a mass of iron forty or fifty feet high would be the same in structure at the bottom as at the top of the mass; for the strength of the metal would resist any change which the weight of the mass would (otherwise) tend to produce. But if there were a cubical mountain of iron twenty miles high, the lower part would be absolutely plastic under the pressure to which it would be subjected. It would behave in all respects as a fluid, inasmuch that if (for convenience of illustration) we suppose it enclosed within walls made of some imaginary (and impossible) substance which would yield to no pressure, then, if a portion of the wall were removed near the base of the iron mountain, the iron would flow out like water from a hole near the bottom of a cask. The iron would continue to run out in this way, until the mass was reduced several miles in height. In Jupiter's case a mountain of iron of much less height would be similarly plastic in its lowest parts, simply because of the much greater attractive power of Jupiter's mass. Thus we see that the conception of a hollow interior, or of any hollow space throughout the planet's globe, is altogether inconsistent with what is known of the constitution of even the strongest materials. * * * The effect of pressure in rendering iron and other metals plastic has been experimentally determined. Cast steel has been made to flow almost like water under pressure.

You may perhaps wonder whether Mr. Proctor, who penned these statements a half century ago, may not have been premature in the making of them, and that later researches (during the greatest investigating age of all time) may have contradicted him. No, he was not mistaken, nor does contemporary science throw the slightest cloud of doubt upon either the facts or the inferences as he gives them. Just as Jupiter was then he still is, and such he has been, according to present scientific opinion, for as long, or even longer, than the age of the earth —say a thousand million of years. Why is he still so hot after a million times as long as (according to the orthodoxical Newcomb), had he been an "ordinary" body, should have been sufficient to cool him down from a solar temperature to a condition such as the moon is in to-day? Jupiter is more than five times as far from the sun as our earth is, consequently he receives only 1-27 as much solar heat, area for area, and the ether that surrounds him is colder than liquid air. Why, I insist again, is he still hot, even to glowing? Shall we follow the example of the Conservationists and lazily sit down and wait for the planet to cool, or shall we not rather seek explanation for the phenomenon in routine natural processes?

By actual experiment physicists have demonstrated again and again that the metal, lead, can be liquefied in the hydraulic press. They interpret this phenomenon in the light of their doctrine of conservation as signifying that in its molten state the metal returns just as many units of heat, *and no more,* as the mechanical energy devoted to its compression. In their haste and obsession it seems never to have occurred to any of the experimenters to watch and wait to see whether the lead will cool off or not; they are content to accept the traditions of their profession as to that. As in the case of the vacuum-tube experiment they prejudge the issue and refuse to be set right.

But let us reason the thing out in a common-sense way. Suppose the experiment to have taken place up to the point where the lead is liquefied, in the cylinder, and still under the full pressure of the piston. We will now assume, to begin with, the possibility that, given time, the lead *will* cool off and become solid, notwithstanding the continuance of the pressure. At this latter stage imagine the piston to be unclamped completely and then immediately reclamped with precisely the same effort as in the first instance, what effect will the proceeding have on the lead? Will the latter be liquefied afresh? How so? Surely the second clamping, by merely restoring the former conditions, cannot compress the ingot to less compass than before; and without accomplishing this much, according to general acceptation, the lead must remain in the solid state. Alternatively, suppose the metal in this case should nevertheless become liquefied; then in the name of reason why did it not *stay* liquid in the first *place?* Again, if no change at all should occur and the ingot under the second application of the pressure retained its solidity just as it was immediately prior to the moment of unclamping, then all the energy expended in the second act, though by premiss precisely the same as in the first, would be utterly lost, not being compensated by any increase of temperature whatsoever in the lead. Shall we then precipitately conclude that, given a *particular* mass of lead that has once before been liquefied by a certain intensity of pressure, it can never again be liquefied save by a higher pressure than other lead samples would require; resulting at the end of a series of such steps in a specimen of the metal altogether impervious to compression? Such a conclusion cannot be true, surely, for it would be tantamount to saying that gold is not always gold, lead not always lead, nor iron always iron.

When Proctor, therefore, speaks of a cubical iron mountain being able to liquefy its base, and when the world of science looks approvingly on and applauds that statement (which it does), they open our way to a choice of these two deductions; (1) that it is the common trait of *all* cubical iron mountains twenty miles high to liquefy their bases, or (2) that *some* do but others do *not*, depending on whether they have ever gone through the performance before. Of these, the Conservationists throughout their ratiocinations show that they unqualifiedly adopt the second as a kind of basic principle, and accordingly they are looking forward to the day when all of Jupiter's mountains of iron, and of lead, and of other materials will have learned not to liquefy their bases and to stay chill against all pressures.

To my mind the thing could not be more obvious than it is, that a mountain of iron which by its pressure once succeeds in liquefying its base will *hold that base in a state of liquefaction indefinitely.* When lead assumes the fluid form in the hydraulic press, it does so simply because that is the natural condition for it to take on when under that amount of stress. When either iron or lead is in the fluid state, it means they are hot because Nature has ordained that fluid iron, or fluid lead, and a high temperature shall forever go hand in hand. The bearing of heavy loads continuously oppresses matter as it oppresses the human slave, the latter experiencing pain and weariness, the former evincing its discomfort in "molecular inflammation," as it were, or heat. Jupiter, like the sun and stars, is hot for keeps.

The hypothesis that heat is an entity independent of matter will not bear the probe of truth. If this were the case, the application of high compression should always produce *warmth,* whereas the fact is it sometimes produces *cold.* Indeed, heat itself is sometimes utilized in producing cold—for instance, in the manufacture of artificial ice and in liquefying air. I allude here, however, more especially to the peculiarity of water in being at its greatest density, not at its freezing point, but at about two degrees above it. Experiment shows that the compression of this mineral does not warm it at all, but actually *colds* it, its temperature depending, not upon the vigor of the compressing power, but upon its own density while under, or not under, compression. Its state of highest density once attained and established, I maintain, will permanently hold the water at a fixed low temperature, provided, of course, that of the surroundings is not greatly altered in the meanwhile. In other words, just as lead under excessive compressions will perpetually maintain a temperature superior to that of the surrounding atmosphere, so will water, under similar compression, maintain a *lower.*

Here we come face to face with a remarkable provision of Nature that is at the same time an indubitable corroboration of this reasoning. We have already called attention to the phenomenon that the earth's temperature increases one degree Fahrenheit for about every 60 feet of depth. At this rate of increase the temperature at 12.480 feet, the average depth of the ocean, should be no less than 212°. In direct contrast with this, deep ocean soundings all over the world have shown that the bottom waters are invariably just a little above zero (that is to say, at the temperature appropriate to water's greatest density). On the one hand, then, we have the earth-body being made warm by compression, threatening the destruction of our planet by the accumulation of central fires; and, on the other, an automatic cooling device for conveying this surplus warmth up through the sea—in its passage serving its own good purpose in tempering the water to the needs of the living creatures that inhabit it. Indeed, were it not for this immense additional source of heat supplied by Mother Earth herself, the oceans would long ago have frozn to a great depth (not solid to the bottom, however, for the reasons shown), and not only would all existing life never have come into being, but it is more than doubtful whether any life whatsoever could have got a start.

From time to time the suggestion is revived to sink a well two or three miles deep for the purpose of tapping the earth's store of internal heat; but nothing has come of it as yet, so far as I am aware. That such a project, if carried out in earnest, would bring with it many surprises, perhaps not all of an agreeable character, is scarcely to be doubted. However, there is an alternative method which to my mind is much more feasible. This is to construct presses of suitable materials capable of bringing to bear the highest possible leverage on, say, a body of lead or iron, imbedded in which should be a coil of pipe made of some stout, refractory material, through which water might be kept circulating. Under these conditions the pressure-liquefied metal would continuously preserve a high temperature and steam would be generated without interruption, according with the capacity of the machine. Just how much pressure would be required in a given case can be estimated in this way:

The pressure of the atmosphere at sea-level will support a column of water 34 feet high, and this pressure is equivalent to 15 pounds to the square inch. If now we assume, what is approximately true, that the material of the earth's crust is three times as heavy as water, and that the temperature of the crust increases at the rate of one degree in every 68 feet (2 x 34) we find that to raise a given substance one degree we must apply a pressure of six atmospheres; and so on for any number of degrees desired.

With this wonderful and inexhaustible source of energy at command mankind can reckon calmly on the future, and view with equanimity the hitherto terrifying prospect that our present visible supplies of unmined coal will become exhausted within the next two centuries. By pressure coolness, too, can be produced, though not to corresponding extremes, by merely allowing water to cool to its lowest point of density and, while in that state, stoutly confining it against future expansion.In this connection, permit another quotation from Professor Stewart (*Conservation of Energy,* pp. 118, 119):

> It may be shown that if the proposition (of conservation) be true, under certain test conditions we ought to obtain certain results—for instance, if we increase the pressure, we ought to lower the freezing point of water. Well, we make the experiment and find that, in point of fact, the freezing point of water is lowered by increasing the pressure, and we have thus derived an argument in favor of the conservation of energy.
>
> Or again, if the laws of energy are true, it may be shown that whenever a substance contracts when heated, it will become colder instead of hotter by compression. Now, we know that ice-cold water or water just a little above its freezing point, contracts instead of expanding up to 4° C; and Sir William Thompson has found by experiment that water at this temperature is cooled instead of heated by sudden compression.

Let us scan the claim Mr. Stewart makes that this instance he speaks of is a "proof of conservation." In the first place, it will not be denied by any Conservationist that the work done in turning the compression screw is equatable in terms of units of thermal energy. Suppose, now, that a flame were applied to the container until the water was restored to the temperature it had prior to compression, and the clamp then released. What now would be the state of our dynamics account in profit and loss in terms of units of energy? On the side of profits there would be positively nothing, while the losses would be treble, and include the mechanical energy of clamping, of unclamping, and the heat of the flame—yet the status at the end would be precisely what it was at the outset!

How much more reasonable to say that when under heavy compression water is naturally cold, and as naturally remains so while the load stays on.

The theory that energy is something apart from matter and that heat is energy, whereas its absence is a negation, does not bear out in practice. If you will take two exactly similar metallic vessels, fill both of them with water and tightly seal them and then place one of them over a hot flame and the other out in the bitter cold, you will learn that both alike will rend themselves. One will burst by gaseous expansion due to heat, the other by the swelling of the water into solid ice; in the former case you must wait until the heat accumulates, in the latter, until the last vestige of it has departed! The result in both cases is the same. Why then do they call heat energy, but coldness not? Again, to produce a quart of liquid air requires the waste of a great deal of heat, but the former, by virtue of its frigidity, will accomplish wonders that heat could never begin to do, *or undo.* The Conservationists will tell you that the work done by the liquid air is in fact a compensation for the thermal energy expended in its liquefication, but what about the work of condensation on the sun performed by the cold of space? Is the inexhaustible cold of space, also, a "product of thermal expenditure?" You see that by every avenue of reasoning we pursue, the truth shines forth that energy is not an entity of itself, but a gesture of matter, and for that reason repeatable indefinitely.

The conductivity of earthy matters is notoriously poor, that of marble, for example, being only about 1-100 that of silver, and brick-earth only about 1-200 of the same. The thickness of a few inches of clay in the walls of a crucible will protect the workmen from a fire within it of two thousand degrees, and more. Now, the temperature of the earth's crust varies at the snail's pace of only one degree for 60 feet of earthy matter. Which, I pray, is the more reasonable inference: that the central heat is oozing out at this amazingly odd rate, or that the temperature gradient is due to the fact of gravistatic heat being generated *in situ?* Anent this subject, let me quote the testimony of Alfred Russell Wallace (*Is Mars Habitable*, p. 40):

> In order that the problem may be understood and its importance appreciated, it is necessary to explain the now generally accepted principles as to the causes which determine the temperatures on our earth, and, presumably, on all other planets whose conditions are not wholly unlike ours. The fact of the internal heat of the earth which becomes very perceptible even at the moderate depths reached in mines and deep borings, and in the deepest mines becomes a positive inconvenience, leads many people to suppose that the surface-temperatures of the earth are partly due to this cause. But it is now generally admitted that this is not the case, the reason being that all rocks and soils, in their natural compacted state, are exceedingly bad conductors of heat.
>
> A striking illustration of this is the fact, that a stream of lava often continues to be red-hot at a few feet depth for years after the surface is consolidated, and is hardly any warmer than that of the surrounding land. A stilll more remarkable case is that of a glacier on the south-east side of the highest cone of Etna underneath a lava stream with an intervening bed of volcanic sand only ten feet thick. This was visited by Sir Charles Lyell in 1828, and a second time thirty years later, when he made a very careful examination of the strata, and was quite satisfied that the sand and the lava stream together had actually preserved this mass of ice, which neither the heat of the lava above it at its first outflow, nor the continued heat rising from the great volcano below it, had been able to melt or perceptibly to diminish in thirty years. Another fact that points in the same direction is the existence over the whole floor of the deepest oceans of ice-cold water, which, originating in the polar seas, owing to its greater density sinks and creeps slowly along the ocean bottom to the depths of the Atlantic and Pacific, and is not perceptibly warmed by the internal heat of the earth.

In boring tunnels through the Alps several independent preliminary surveys are made with infinite care, so that the work may be prosecuted from both ends at once with the certainty of accurately meeting in the middle. What would the chances be of meeting thus fortuitously? Now, we have just such a parallel instance in the case of the earth's heat, for, just about five feet under the surface the temperature is uniform the year round and exactly the mean of that of the atmosphere above. How comes it that scientists have never thought worth while to comment on this amazing coincidence,—that the heat alleged by them to have been implanted in the earth tens of millions of years ago, and ever since engaged in escaping, should, just in our day and hour, happen so precisely to match the mean surface temperature, which owes itself to a totally independent cause! What was the temperature a hundred feet below the surface a hundred, a thousand, a million years ago? and, since theoretically so much hotter than now, what should have been the effect upon animal and plant life?

If current theory were really correct, our planet would be a very unsafe one to dwell upon, for a central heat of 300.000° (as indicated by the temperature gradient) would speedily disrupt it, or, rather, there should now be no earth. According to my theory, the rate of such increase, being dependent on the strength of gravity, must diminish the farther down we get, so that the maximum calculated temperature would not be more than half the amount stated. As a matter of fact, it is far below this figure, because of the extensive internal water-circulation that doubtless exists.

Were the planet ever to increase to a great size, like that of Jupiter, for instance, the intense heat generated would quickly dissipate the present oceans, and in time cause the earth to acquire the same general characteristics as that giant orb.

We thus see that the earth's economy provides what it demands, a running supply of heat, and a uniform one. The extreme secular variation implied by the kinetic theory, as currently understood, or by the radium theory, would have proved just as inevitably fatal to earth-life as a secular variation in the sun's temperature. Nature does not dole out treasured heat, but evolves it as she goes along, and with the same lavishness she displays in all else.

In this process of *gravistatic-heat* production we have the clue to why the universe did not long ago perish by agglomeration into a single mass, and why it never can do so. Without some adequate dispersive force, constant mutual attraction must prevail in the long run and in the end bring about a crash that should leave nothing but a stupendous clinker to mark the tomb of Nature.

It is inferrable that all matter has run the celestial cycle many times, so that the chances are a myriad to one that a given planet has not grown by simple accumulations of primordial dust, but owes its nucleus to a fragment from its own sun or a neighboring star. Or, rather, to fragments, for the stars are unquestionably plastic, so that the future planet gains separate existence in the form of a jet of coarse spray divided into many globules, which separately congeal and afterward cling together as a unit when their mutual attraction triumphs over the unequal dispersive effect of the explosion that begat them. That all planets are spherical, follows from the law of gravitation, provided their parts are sufficiently small or mobile. Were the fragment but an irregular and very rigid block its future shape would depend upon its size alone; one very large would melt with the fervor of its self-generated heat, whereas a small one, such as an asteroid or a meteor, might be and stay any odd shape.

## LIFE IN THE UNIVERSE

One of the labors of the chemist is to synthesize compounds for various uses in the arts, and in the pursuit of this object he is often obliged to try hundreds, perhaps thousands, of combinations and permutations before he attains the particular end he desires; if he attains it at all. Thus far, science has never succeeded in experimentally synthesizing protoplasm, the basis of life, or, at least, protoplasm that actually *lived.* Speculating with regard to gravitation, we may well ask whether that power which, as we have seen, inspires all the activities of the universe, may not, directly or indirectly, be the secret of life—whether, so to speak, life may not be a sort of idealizied form of it, the "will-to-live" of Schopenhauer. In the sun, in every star, in every planet, indeed, we see the crucibles in which Nature tries out her materials, combining, dissociating, and recombining them, again and again, endlessly, to work out her evolutionary purposes. When, finally, the star explodes, its scattered parts, though in the main alike, nevertheless carry severally something unique in their chemical make-up that has its peculiar cosmic value. Is it, then, unreasonable to conceive that some one, or many, of these may fortuitously contain in generous measure all the ingredients of this mysterious protoplasm, and, becoming buried in the planet far enough from the surface to enjoy just the right degree and uniformity of gravistatic temperature requisite for prolonged incubation, in the end germinate life?

The size of a planet determines its character absolutely. If over-large it generates too much gravistatic heat to make life possible on its surface; if too small, it does not generate enough to keep its oceans from freezing, and life is again rendered impossible. Since however, it is the nature of planets to grow, such as are too small, like Mars and the moon, may hope one day to emulate the earth in fecundity, but the major planets are doomed to perpetual barrenness, although they may once have been viviferous.

A close analysis of these and many other facts, such, for example, as the inclination of the earth's axis, the small eccentricity of its orbit, the nice adjustment of its size "gravistatically" to the work required of it, its favorable distance from the sun, the possible fortuity involved in the origination of life, etc., make it seem not entirely impossible that terrestrial man is the only creature in the universe capable of comprehending and appreciating its stupendous beauty and scope. The thought has its terrors as well as its inspiration.

The evolutionist, the physicist, the geologist, the biologist, may all find in gravistatic heat the explanation of many of their enigmas; such, for example, as the assimilation by Nature of her heterogeneous substances into combinations beneficial to plant and animal life; or the distillation of mineral gases, oils, and the like; or the internal structure of the earth; or the explanation of marine life, and so on.

Having passed the habitable stage, nothing lies in store for a planet but to grow up into a sun or a star, with a retinue of planets to circle around him. Eventually his Gargantuan appetite for devouring lesser surrounding bodies will create of him a vortex menacing to the integrity of the universe, and Nature in very self-defense will have to decree his extinction. One day comes the crisis. In an instant his huge bulk bursts asunder and is scattered broadcast, with the speed of light, into surrounding space. Some fragments enter other systems carrying with them more or less gravitational disturbances; but most of his substance remains within his whilom domain in the form of a nondescript nebulous cloud enveloping a hailstorm of meteors and larger fragments that instantly begin the process of equilibristic readjustment to the altered conditions; a process requiring a year of ages, and ending at last in a new system of worlds.

Here among the stars, then, do we find Nature acting consistently with her established order on earth; building only to tear down, bearing children that they may die, creating, so there may not be wanting something to decay. Or shall we not rather reverse the philosophical order and say, that she destroys only that she may improve, that she sacrifices the individual, not wantonly, but for the sake of the well-being, salvation, and evolutional development of the universal Whole?

This destruction of stars is as sure as fate, and seemingly as fortuitous as is physical death among mankind. What star shall be the next to explode is a matter of inscrutable chance, and for this reason the stellar map is so wanting in symmetry. But symmetry never has been, nor ever will be, either a guaranty of permanence nor a consummation devoutly to be wished. That variety is the spice of life is a truth recognized by Nature long before she ever thought to create man. Ruling though she does by the most inexorable of laws, she yet manages to evolve infinite diversity, so that no two objects are ever precisely alike. Planetary systems, planets, men, flowers, snowflakes, though faithful types in all things of their respective classes, yet possess individual traits distinguishing them from all others of their kind.

## XII

# THE PLANETS MARS AND VENUS

NEXT to the earth itself, Mars is by far the most interesting of the primary planets, notwithstanding that it is the second smallest. The reason for this lies partly in the fact that on account of its nearness and its favorable location for observation we can obtain a closer and better view of its surface than we can of any other planet, but mainly in the mystery of its so-called "canals" and the question as to whether it is inhabited by an intelligent race of beings. When very closest to us, Mars is still over 35,000,000 miles distant, and this distance varies all the way up to 250,000,000 miles, depending on whether the planet is on the same side of the sun as the earth or not. Inasmuch as the diameter of the planet is only about half (4,200 miles) that of our earth, simple computation will show that, when very nearest, it subtends the same visual angle as a 25-cent piece does at a distance of 700 feet! It should therefore not surprise the reader to learn that there has been a great deal of controversy between first-class observers, armed with the best of instruments, as to whether the "canals" exist at all, not to mention the even more indistinct details which Lowell and others claim to have detected.

The first astronomer to call attention to these lines on the Martian map was the Italian, Giovanni Virginio Schiaparelli (1835-1910), in 1877, who called them *canali*, which, it is said, does not precisely correspond in meaning with the English word "canals" as subsequently employed to designate the same marks. With the closer study of these mysterious lines as his main object, Doctor Percival Lowell (1855-1916) established, in 1894, an observatory of his own at Flagstaff, Arizona, and a year later propounded his now celebrated hypothesis that the canals are the handiwork of a race of intelligent beings who still inhabit the planet and continue utilizing the canals for the purpose for which they were laid, to wit, irrigation.

The fact that Mars is half again as far from the sun as we are, diminishes, of course, the amount of light and heat it receives. This quantity, varying inversely with the square of its distance, amounts to less than four-ninths that which the earth enjoys, area for area. Needless to say, the effects of this deprivation of the chief requisites for the preservation of life, assuming its existence, must be very serious indeed, and they constitute one of the chief difficulties to be overcome by the advocates of the Lowellian contention. The surface gravity of the planet, whose mass is but 1-9 of our earth, is reckoned to be 38 per cent as great, so that a rock which on our planet would weigh a hundred pounds would scale but 38 pounds there.

According to Doctor William H. Pickering, who, now that Lowell has passed beyond, is probably esteemed the chief authority on Mars in this country, as he has long been on the moon, in his article in the *Americana* on the planet describes the canals and other surface features in these words: "They consist of narrow dark lines, generally straight, forming a network over the whole surface of the planet. At their junctions we often find small black dots, known as lakes or oases. Large areas of the planet, called seas, are of a dark gray color, but most of the surface is yellow, or, if observed by daylight, orange. The cause of all the dark regions is probably vegetation, with the exception of the two very black lines which are seen to surround the snow caps when they are melting. These two lines are temporary in their nature, and form the only true oceans of the planet. Occasionally they attain a breadth in some places of 300 or 400 miles, and are then found to be of a dark blue color. The polariscope shows that, unlike the rest of Mars, their surfaces are shiny. The yellow regions are thought to be deserts. They cover more than half the entire surface. Very marked changes sometimes appear in the finer details when the snow is melting most rapidly. At the approach of the Martian autumn those parts of the dark areas that are near the poles are seen to fade out and turn yellow so as to be indistinguishable from the soil of the planet.

## LOWELL'S THEORY OF AN INHABITED MARS

Doctor Lowell had long been a close student of Mars and a prolific writer on this his favorite theme, when, in 1909, he published his *Mars as the Abode of Life,* in which he summarized the whole subject. As basic facts, besides those enumerated above, for his theory, he cites the following (I quote his exact words only in part):

1. ''The northern snow-cap diminishes from 78° to 6°, the southern dwindles from 96° to nothing.

2. ''Mars' surface is singularly devoid of irregularities. The more minutely it is viewed the more its levelness grows apparent. Calculation shows that heights even of very moderate elevation should be visible if such existed and none show.

3. ''Excluding the polar caps, the surface consists of large robin's-egg-blue patches indiscriminately placed upon a general background of rose ochre, the relative areas being 3/8ths to 5/8ths. The tints frequently vary in shade and grade off insensibly into each other, thus making regions of intermediate color but the precise borders of which are not decipherable by the eye''. The ochre regions he construes to be deserts of sand and rock intrinsically of that color. ''White dots too are scattered over the disk, dazzling diamond points that deck the planet's features to a richness beyond the power of pencil to portray, so minute are they that good seeing is necessary to disclose them''.

4. The fact that the canals appear on the dark blue regions as well as on the ochre leads him to assume that both are land; the former, in his opinion, being probably the basins of evaporated oceans and now covered with vegetation.

5. The canals follow the arcs of the planet's great circles, so that we who look centrally down upon them see apparently straight lines. This studious regard for choosing the shortest distance, he opines, implies not only provident economy in design, but also a very high degree of technical knowledge and skill. Necessarily, there are many points of intersection, and, strange to say, at the majority of these there are circular dots about 75 miles in diameter, which in color correspond with the canals. These Mr. Lowell conceives to be oases, Martian cities, as it were, environed by irrigated farms. Not this alone, these canals connect with certain caret-shaped spots that appear to be the "salient points" of the blue-green patches; and from certain of the oases canals branch out numerously, always in straight lines, to other oases, forming a sort of open network. They always lead to definite destinations, never stop short as rivers might do, and, again unlike rivers, they preserve a surprising uniformity of line throughout.

6. In the first days of summer of each hemisphere these canals, he states, begin to grow in distinctness, starting at the polar cap soon after it commences to thaw and thence gradually continuing down to the equator. At such times, too, certain of the canals have a trick of pairing or doubling, technically known as "gemination".

7. The aggregate length of the canals is enormous, probably as much as 40,000 miles, or three times the circumference of the Martian globe. Five hundred and twenty-two of them have been mapped, the shortest being not less than 250 miles in length and the longest, the Eumenides-Orcus, stretching the enormous distance of 3450 miles. At least a dozen extend to points far within the polar circles, and would no doubt be found to reach even to the pole itself, were their ends not obscured by

the sharp retreating figure of the globe in that high latitude.

After thus carefully setting out his facts, Mr. Lowell proceeds to his theorizing somewhat as follows:

1. According to the molecular theory and the mathematical analysis by Clerk Maxwell, the molecules of hydrogen possess velocities of about seven miles a second, which is slightly higher than the critical, or parabolic, velocity at the earth's surface, and very much higher than this same velocity at the surface of Mars. Now, Doctor Johnstone Stoney has suggested that a logical consequence of this molecular pecularity should be that small bodies like the moon would, because of their feebleness of attraction, gradually lose these swifter-moving molecules and, in the course of years or centuries, become denuded, not only of a large part of their original atmosphere, but more particularly of their original supplies of water, of which mineral hydrogen is an indispensable constitutent. As scientists in general concede this deduction of Doctor Stoney, and as the dead moon is universally believed by them to be devoid of both air and water, or practically so, the inference is that Mars, though more slowly, is following the moon's example and gradually deteriorating into a desert planet at the end of a protracted period of exalted biological development. Mars, then, Mr. Lowell concludes, is an *arid* planet, and to its inhabitants, if any, water must be at a very high premium.

2. Water is essential to life. There being no oceans, the streams too must be dried up. The alternative is presented of death from thirst, or of recourse to the only fresh water supply remaining, to wit, the polar snows.

3. Naturally this necessity prompted to the Martians the canal idea. Of course the system now in evidence was not constructed in a day; it was the result, rather, of slow growth, developing painfully in inverse ratio to the failing sources of supply.

4. The undertaking, he opines, was far less formidable than a similar one would be here. First of all, the flatness of the surface would obviate much grading and leveling. Then, again, on account of the lesser surface gravity, the efficiency of the machinery would be perhaps quadrupled. If to these positive advantages be added the suppositions that the Martians are gigantic, and further advanced in the mechanical arts than ourselves, the objection on the score of mere physical difficulty is largely reduced.

5. The surface being flat, every point within as well as beyond the polar circles would be in stable equilibrium. This means that the water would not descend through the canals at any useful speed without artificial propulsion. Observation proves to him that the canals show activity of a certain kind immediately following the incipient thawing of the snow-cap, and that this active movement travels equatorward at the rate of 51 miles a day for a distance of 3300 miles. As to the nature of this change we can judge only from appearance, which consists in a gradual darkening and broadening of the canal lines, and this is construed by him to be due to stimulated vegetation along their borders.

6. The ancient "sea bottoms", he infers from their color, are regions of vegetation. Yet they too exhibit "canals", not only entering from the nearest pole of supply, but rising again into the arid regions nearer the equator. This feat of canalizing the basin of an ocean and thence raising the water to the farther shore Mr. Lowell cites as a striking evidence of Martian engineering prowess.

7. The distance of Mars from the sun, its source of heat, is not so great as absolutely to preclude the existence of animal life. Mars' summer is much longer than ours, and planetary life is determined rather by the mildness of summer than by the asperity of winter. Mars' mean temperature he estimates at about 48° F.

8. Unlike the snow caps of our Arctic and Antarctic

regions, those of Mars are not permanent, but disappear all but totally every recurring summer season, and are redeposited during the succeeding winter with the same unfailing regularity. Reminding us of the fact that the solar warmth is only 4-9 as great as here, Doctor Lowell argues from these two premises combined that the polar snow deposits must be very scant indeed to be so easily and quickly dispersed.

9. Philosophically speaking, the evolution of life from matter is the order of Nature. Mars, whether or not older than our planet, presumably cooled earlier, both because smaller in size and more remote from the sun. Hence it has already run the gamut of evolution, and, by the principle of survival of the fittest, the present Martians must be the highest products of their race. Historically, they have witnessed the birth of a world and seen it pass through its seven ages into that of the sere and yellow leaf. Even the seas have dried up, partly by absorption into the interior and partly by the escape of the molecules into the outer air. The race is at bay, being driven slowly, but none the less inevitably, to extermination by the road of thirst; for the snow-caps must be thinning year by year, and eventually must altogether vanish never to reappear.

## *Criticism of Lowell's Theory*

As a scientist, Doctor Lowell was an excellent fictionist. Becoming early enamored of his pet idea, he pursued it relentlessly, in season and out of season, twisting the most intractable of facts to suit his preconceptions; reasoning not to a conclusion, but to support a conclusion previously irrevocably resolved upon. Let us scan his arguments dispassionately with the view of allowing ourselves to be guided by the plain facts rather than by predilection.

1. First of all, there is the question of temperature —climate. When we say that the sun sheds only 4-9 as much heat on Mars as on our earth, what does the state-

ment mean? By general understanding, Mars, without any solar warmth at all, would possess a surface temperature in the neighborhood of the absolute zero, or —461° F. and so would the earth. Even receiving the generous quota of heat we do, the mean annual temperature of New York City is only 53°, of Pittsburgh, 62°, and of Flagstaff, where Lowell himself was stationed, 58°; in other words, the sun's heat, according to common acceptation, serves to raise the superficial temperature of our planet 60°+461°, or 521° F.! Four-ninths of this number is 232°, which being deducted from —461° gives us the exceedingly low average temperature for Mars of *229° below zero, or 261° below the freezing point of water!* This is surely a long way from the +48° F. that Mr. Lowell *claims* to have derived as the mean temperature for that planet!

2. Vegetation is the food basis of all animal life. Even granting a decline of but 20° in our mean annual temperature, complicated with the same sort of disastrous fluctuations we have now from week to week, day to day and even hour to hour; what food of value for the sustentation of human life could be grown outside the tropics? And allowing *there* a reduction of an *additional* twenty degrees would inevitably put an end to all terrestrial vegetation, save weeds, grasses and non-fruit bearing trees.

3. And did Professor Lowell in his zeal really succeed in persuading himself into the belief that, given sufficient *ice-water,* vegetation in the arctic zones would proceed as speedily as in the tropics? His own words leave no room for doubt that such is his meaning. For, blindly enamored of his theory, he proceeds, in close logical sequence, to describe how first the coming sun thaws the snow cap, then how the water is made to descend by artificial aid toward the equator in the timed flow of 51 miles daily for the huge distance of 3,000 miles, and how, *in precise step* with this flow, the canals, *beginning with the uppermost in latitude,* successively darken with the revived growth of vegetation. Dramatically he contrasts

the regular *pole*ward trend of our sprouting season with the *reversed* order on Mars, and seems to derive a discoverer's elation from the circumstances that one is as *regular* and *sequential* as the other! Now, there are three conclusive answers to this pretty fancy which Mr. Lowell, for the sake of bolstering up his pet idea, studiously ignores. One is, that unless Mars were much hotter than our earth, the frost in the polar latitudes, where Lowell assumes vegetation to get the earliest start, must be perpetual, and vegetation altogether impossible, whether with or without water, be it warm or cold. The second reason is, that the water freshly melted from the polar drifts would be veritable *ice-water,* and would be no stimulant to plant-life in a warm, let alone in so frigid a climate; and, third, it is only by screwing up his estimate of Mars' temperature to the last notch that he can convince himself or others that life, *even on Mars' equator,* is possible, not to speak of canals and oases *at its very poles!* Then there is the sensible, economical reason, that the canny Martians of the tropics, did they actually exist, should long ago have learned to take thought for the future and to provide stores of water against the opening of the new season, so as not to be dependent upon their Esquimaux for their early spring vegetables!

4. The southern snow cap at the full covers over a quarter of the planet's surface, and the northern cap considerably more than a fifth. The snow must come from evaporation, must it not? But Mr. Lowell denies the existence of any evaporating surface save only of his canals! Were the caps a *permanent* feature, this point might be overlooked; but the snow disappears every summer, and of course must be as often restored. It seems to me that if Mr. Lowell had not had his fantastic theory in mind, he would have reasoned, sensibly, that the caps could not come into existence from the evaporation of his canals alone. The caps being so extensive, and the solar heat so feeble, *there must exist an exceptionally large evaporating surface.* He might have reasoned further that the vapors from the canals wouldn't extend

his theory the courtesy of proceeding intact back to the poles, but would, after the manner of atmospheric humidity, spread in all directions, and come down in rain or snow indiscriminately over the whole surface. His snow eggs are laid without the aid of the mothering ocean.

5. On a planet where warmth is surely as much of a desideratum as water, we should expect to find settlements only in the very warmest belts. The hypersophisticated Martians, however, have proportionately as many canals and oases in the very heart of the arctics as in the best favored regions, and, marvel of marvels, underneath the very snow caps themselves! For proof, consult Mr. Lowell's published maps.

6. Since these canals appear to be feasible everywhere, why did it not occur to the Solons of the planet to surround the snow supply with a belt line, and thus save themselves the manifestly superfluous task of boring a multiplicity of canals through countless miles of what must be hard-frozen soil?

### THE AUTHOR'S VIEWS ON MARS

Analogy teaches us to expect seas on Mars, and until better proofs are brought forth than have yet been advanced in rebuttal of this reasonable presumption, we are logically bound to favor it against highly speculative hypotheses such as that of Lowell's. It must be confessed that there is something wonderfully fascinating, to myself as well as to the Lowellians, in the idea that on the planet so near us there may be a race of supermen with whom future earth-born generations may one day hope to communicate, if only by signals; but let us not allow this fancy to cloud our sober judgments. Those of us who do not care to surrender the idea may keep on clinging to it if they like, but for the sake of truth and sanity let us not wittingly deceive ourselves with plain delusions.

There is a maxim of law, "Where the reason of the law ceases the law itself ceases," and the spirit of it may well be applied in this place. What purpose are the canals intended to subserve? Lowellians reply, "Irrigation". If it can be shown, then, *that there is an ample supply of clouds and moisture on Mars,* the *motive* for building the supposed canal system falls, and the whole theory perishes with it.

When the first edition of this work was in preparation (1911) I sought almost in vain for published testimony supporting my deduction (from my theory of tidal rotation) that Mars is plentifully supplied with oceans; and though more of such testimony may have existed at the time, all I could uncover was what is contained in this paragraph, quoted from that edition:

> In one place in his book, Mr. Lowell graphically describes a great Martian storm, in which the cloud was estimated by him to be flying at a height of 14 miles above the planet's surface. He expresses the opinion that this cloud was composed of sand, "because its color was almost that of the planet's surface," which, as we already know, he assumes to be desert. Now if correspondence of color between surface and cloud counts for anything, then the cloud, according to my theory of a frozen-over ocean, should have consisted of snow; and the issue narrows as to whether sand or snow is the likelier element to be found at an altitude of fourteen miles in a case where the atmosphere is admittdly rare.

Since that year, however, two oppositions of the planet (which occur about two years apart) have taken place, and it has been most carefully studied by a chain of expert observers in various parts of the world led by Prof. W. H. Pickering himself; and by him the results have been elaborately reported, with photographs, in *Popular Astronomy,* beginning with its January, 1914, number. From these articles I cull only a small part of a great wealth of material to the same effect:

> The clouds are sometimes so widespread and numerous, or perhaps so thin, like our cirrus, as to partially conceal the detail of a whole hemisphere. This was the case in 1894, and again at one of the more recent oppositions. Photography shows (*Harvard Annals* 53, 167) that an equatorial belt of cloud is often present, but this must be very thin, since it has not as yet been observed visually. As regards color, it may be noted that our own terrestrial clouds are by no means as white as snow. Sometimes when the sun is low and behind us, two clouds may be seen,

the nearer of which is much darker than the other, though it is not possible for either of them to be in shadow. The cause of this seems to be a matter of theoretical interest which has been neglected by our meteorologists.

The more conspicuous Martian clouds lie along the limb of the planet, where their existence can be most readily detected by their irregular distribution. They are also found upon the terminator, especially near opposition, but on account of their wider separation from one another they are not so conspicuous there as upon the limb. Since they are found both at sunset and sunrise, it is believed that cloudy nights are not infrequent upon the planet. On account of its comparatively low pressure, the atmosphere of Mars must at certain seasons contain a larger proportion of water vapor than that of the earth. Some of this would be precipitated at night by the cold, and cloudy nights are therefore what we might naturally expect.

It is believed that the annual circulation of moisture from pole to pole takes place upon Mars as upon the Earth, chiefly by floods and through the atmosphere. Upon the Earth our floods are taken care of, except in a small way, cosmically speaking, by our oceans, but on Mars they must be much more severe. Even upon the Earth, however, where large masses of land occur and the snow fall is heavy, as in Siberia, the spring floods offer a startling demonstration of the intensity of our sunlight. Compared to one of these huge Siberian freshets, our own western floods sink into insignificance.

On January 13, 1914, Professor Lowell reported that the Martian southern cap was beginning in stippled patches of hoarfrost, between longitudes 30° and 60°. Our own next view of this region was on February 7, when it was occupied by a cloud 1200 miles in length. The cloudy area increased in size the next night to 1800 miles, but two nights later was again smaller measuring 1500 miles. February 12 it had entirely disappeared. The following night all the south polar regions were recorded as very dark, with no trace of cloud. February 14 a crescent of haze lay along the whole length of the limb and part of the terminator, extending half-way to the center of the disk, entirely concealing the polar regions. After this the area in question passed around to the other side of the planet, and we saw no more of it. We are quite clear however that there was no hoarfrost or permanent snow area there on either February 12 or 13. The writer does not believe that the hoarfrost is ever seen far from the sunrise terminator, and he would suggest that what Professor Lowell interprets as hoarfrost is described here as cloud. The appearance noted here has a white pearly lustre, clearly fainter than the snow at the north pole, but brighter and much whiter than the desert areas of the planet.

White cloud is occasionally seen in the equatorial regions close to the limb, but when it gets nearer the center of the disk it turns yellow, owing doubtless, as previously stated, to its thinness, and to the fact that we see the soil between separated small clouds. Our own cumulus clouds often have a bluish tint, even near thin centers, when they are forming or dissolving, and are therefore thin enough for us to see our blue sky through them.

It is the writer's impression that the meteorology of Mars resembles very closely that of the earth, much more closely than has heretofore been supposed. Clouds are numerous on both planets but they are more so in the daytime with us, and possess greater density. It is believed for theoretical reasons that the northerly and southerly components of their winds are more marked than ours, that their daily range of temperature is greater, and that their precipitation usually occurs at night, but except in these respects the meteorology of the two planets is practically identical. * * *

For many years Martian observers have been in the habit of reporting marked changes as occasionally occurring upon the planet, but the writer believes that a considerable proportion of these, perhaps a third, were due simply to shifting clouds. Thus the numerous and marked changes in size of the southern polar cap at this opposition are almost certainly due to nothing more complex than the formation and dissolution of cloud areas. The sudden appearance of two lakes and four canals in the Protei Regio on December 31, where on the previous night only a whitish area was visible, was presumably due to the clearing away of clouds. Possibly the fact that certain narrow canals were seen south of the Sabaeus in January, which were not seen on February 14 to 16, though near the center of the disk, with seeing 12 and 10, is due to their having been hidden by invisible, because partially transparent, cloud masses. (April, 1914)

When any of the large polar marshes, but especially Acidalium, come around the sunrise limb, they are usually followed at a distance, sometimes as great as 200 miles, by a yellow or white area of considerable size. The former color indicates cloud, and is the commoner of the two. The white probably indicates a thin layer of new fallen snow. It must be thin, since it never persists to the central meridian. On October 9, Martian date February 48, a pure white area one-third the size of the polar cap and of the same whiteness and brilliancy, following the Adicalium marsh stretched from the sunrise limb to within 45° of the central meridian. It must have been an unusually heavy fall for Mars, for this would indicate that it persisted until nearly 11 o'clock in the Martian morning. Its size was rather difficult to determine for, unlike the snow cap, it had no sharply defined southern boundary. It stretched about 600 miles south from the polar cap, or through some 16°, to latitude 37°, and must have covered nearly a million square miles of surface in the visible hemisphere, and very likely much more on the other side of the planet. (Dec., 1915).

The snow cap is now appreciably smaller than it was at the last opposition, at the same season of the year. Since as we have already seen it was much larger earlier in the season than at the former opposition, we can hardly doubt but that they have been having rather warmer weather on Mars this year. It will be of interest to note if this means a warmer summer than usual for our Earth.

It may be mentioned here that although we have watched the planet under very satisfactory circumstances throughout the whole of the spring of its northern hemisphere, yet not a trace of green has been detected in that region. The impression gathered has been that all the dark northern areas, and most of the canals observed have been simply marshes, or moistened soil. Possibly greens will appear in their autumn or before. On the other hand the greens of the southern hemisphere, during their autumn, have been at times very striking. They have now all disappeared.

The writer would point out that the clouds always lie over the so-called desert regions of the planet, apparently being precipitated as soon as the fertile regions are reached. This is clearly shown in Figure 14, where the cloud following Charontis is also indicated, half covering Elysium. This was not an unusual feature in this region in the Martian mornings, indicating doubtless that Charontis like Acidalium is composed of moist or marshy land. Incomplete canals, i. e. elongated marshes, disappearing in the desert, are shown in many of the drawings, by most of the observers. Such a thing like an incomplete canal was formerly supposed not to exist. (Dec., 1916).

Unlike our polar ice caps, which are perpetual, Mars' snow caps totally disappear every recurring summer season, and just as regularly reappear during the ensuing autumn. This circumstance has led Lowell and astronomers in general to suppose that the snow sheet must be exceedingly *thin* to yield so completely and so readily to the sun's warmth, especially when it is remembered how feeble must be the solar rays, not simply at Mars' distance but at his *poles*. Their error lies in assuming that there is only one way by which snow can be dissolved, namely, by heat; whereas there is this other—BY FLOODING. Lowell, in words almost emphatic, describes Mars as being remarkably smooth, or level, no roughness of any sort being discoverable on his surface. We have only to surmise, then, that in the frigid season the polar oceans freeze solid and *dry,* thus supplying a resting place for the snow, and that, during the warm season following, this ice either disintegrates and loses itself, along with its cargoes of snow, in the ocean; or that the ice fields are periodically swept over by tides from the warmer equatorial zones; or that the rains wash down the snow until it turns to slush and so loses its virgin whiteness. Surely, there is no mystery here!

Mars' polar caps are *exceptionally extensive,* and for their production demand the existence of a *relatively large ocean surface.* This requirement is rendered more imperative by the sun's remoteness, and is even further accentuated by the compulsory exclusion from the available evaporating surface of that part of it covered, for the time being, by the opposite cap.

If Mars' seas bear a similar ratio to its solid kernel as ours do to the earth's, three-fifths of his surface must be covered to the depth of a mile or more. This assumption, it may be said, is sustained by my theory that the earth's axial rotation is due to the sun's tidal action. Mars rotates on its axis once in 24 hrs. 40 ms., a period reasonably consistent with the earth's case, especially when their respective masses and solar distances are taken into the reckoning.

The center of gravity of Mars (according to my argument regarding the earth) lies toward its north pole, and conformably we can see the outcropping of land there revealed by the *persistent* presence of 6° of northern cap, whereas the southern cap seasonally disappears *completely.*

The conclusion is inevitable: *The hitherto supposed "lands", with the possible exception of the blue-green patches, must, after all, be* SEAS, *and the riddle of the markings must be solved on this basis.*

Now, it goes without saying that oceans in their fluid state often exhibit great waves; but these quickly vanish and leave no permanent signs. The insistent reality about Mars, however, is its *frigidity,* and this fact ought long ago to have prompted the thought that the oceans may be normally *frozen over*, in which state they can as easily carry surface markings as the most rigid land, and more regular ones, besides.

It would be an error to jump to the conclusion that Mars' oceans must be frozen *solid,* for decidedly they are *not.* For one thing, the planet could not rotate unless they were *mobile,* as I have previously shown; and, for another, the gravistatic heat generated by the planet is probably sufficient to prevent total congelation. Nor should we fail to bear in mind, that the water at the bottom of a deep ocean *cannot* freeze, because of its density there being constantly maintained above that required for freezing.

That Mars' gravistatic heat is by no means a neglibible quantity may be proved by a simple calculation. Mars' superficial gravity being .38, one would have to descend toward his center about 150 feet for each degree of increase in temperature, yielding a maximum theoretical temperature at that point of about 40,000 degrees, or an average of 20,000 for the whole mass. This is a much lower temperature than our earth theoretically generates and may seem insufficient until we call to mind that Mars' rarer atmosphere and lesser gravity both operate to greatly lower the freezing point of the water, and that ice is a bad conductor of heat as compared with convection currents in a purely fluid sea.

The excessive external cold must evince itself somehow, and this it does by freezing a thick crust over a major portion of the ocean surface. Nevertheless, even such a surface may experience seasonal changes, and this is the real key to the whole mystery. It remains for us now only to reason by natural steps just what would take place under such conditions.

Going toward our own north pole we come eventually to a parallel of latitude of perpetual frost. In the case of Mars this critical parallel is nearer the equator than it is with us. During the warm season the ice-crust thaws to the depth of a very few feet, but not entirely through, except, perhaps, very late in the season, and then only right at the equator where the crust is thinnest. So cold must be the planet that the sun would be powerless to cause evaporation were it not for the accidental circumstance mentioned a moment ago that, on account of the diminished surface gravity and lower atmospheric pressure, the boiling point of water there is reduced from our 212° F. to about 100°, and the thawing point correspondingly.

The process of evaporation takes place from the surface of this glacial crust, or rather from the surface of the thaw-sheet submerging that crust, during the daylight hours of Mars' protracted northern spring of 199 days and his scarcely shorter summer of 183 days. The nights are relatively cold, and during them much snow falls upon the thaw-softened surface, thus giving birth in the course of time to a vast superficial litter of disintegrated ice extending far into the high latitudes.

When this condition reaches a maximum, this superficial sheet of thaw-water is of itself sufficiently deep (or perhaps is sufficiently reinforced by the subjacent waters breaking through the softened crust at or near the equator) to reflect in its movements the tidal effect of the sun. Waves of wide scope are formed, which progress with a high degree of regularity over the smooth, solid ice shelf, sweeping the glacial detritus before them until, having reached the limit of their range, they deposit their cargoes in long, geometrical tidal lines, which then form embryonic ridges, or dams, for future waves and new cargoes to respect and add to; until in the end the accumulations grow to a width capable of arresting our attention even over this vast abyss of space. Veritable congealed tidal waves are they, following, by the very law of their formation, the great circles of the planet, and supported from beneath by the continuous, far-spreading, permanent ice-crust. As the sun moves northward or southward, the new waves that keep forming take slightly different courses, and give rise to new "canals."

Now, when waves touch or cross they "interfere," and create at the points of intersection hills of double height and width. This, I take it, is the origin of the "oases", and of the curious "carets". On this theory it ceases to be mysterious why both canals and oases are so segregated, why so many of them affect the polar regions, and why they connect the "salient points."

The dams, being composed of ice, would melt away were they not seasonally recruited. But they *are* so recruited, as the gemination process eloquently attests. The seasonal or capricious lightening and darkening of the canals may be aptly explained by fresh snowfalls, or by the meltings of old snows; doubtless as common and natural climatic phenomena there as here, and not especially significant.

The same explanation ought to suffice for similar *general* variations of color. The brilliant white diamond points which Mr. Lowell describes can assuredly be nothing else than islands capped with snow—his own theory of an exclusively land surface precluding him from advancing the same natural solution. Should any of these ever be detected changing its place, it could be explained as a floating iceberg decked with snow.

My conclusions, then, as to the character of Mars' surface are: *That the planet is largely enveloped by its oceans; that these in turn are frozen into great solid, unbroken ice-blocks reposing on their pressure-liquefied bases, and that whatever markings and irregularities may exist on their surfaces, whether comporting with Mr. Lowell's reported observations or not, are the natural result of seasonal changes and tidal wash. Under these conditions the planet is not habitable by any but the very lowest forms of life, and can never in the past have been any better fitted to support life than it is to-day.*

## THE PLANET VENUS

We have now seen that the proportion of water, in one or another of its forms, to the solid ball is practically the same in the cases of both Mars and the earth; and we seem therefore constrained to conclude that the same thing is true of Venus. Now, since Venus is almost as large as the earth, its gravistatic heat suffices to preserve its oceans in a fluid state, all the more so from the fact that it receives about twice as much solar heat as does our planet. Venus therefore rotates on its axis. Again, since the planet is so close to the sun, its atmosphere is immensely more humid than ours, and its surface consequently shrouded in perpetual and universal fog; so that we can never hope to obtain even a glimpse of its real face.

If, now, we assume that life is not a happy accident of Nature's, but the inevitable outcome of her inherent energies and laws, we are driven to admit the existence of life on Venus, but not necessarily of intelligent life. Judging from terrestrial analogy it should rather be marine and amphibian in character, on account of the difficulty of lung-breathing; and, moreover, it should be confined to the arctic regions because of what must be the insupportable torridity of Venus's lower latitudes.

## XIII

## THE MOON

THE general reader would naturally suppose that since we are able to form an idea regarding the character of Mars' surface, which, at the best, is more than 140 times as far from us as is our satellite, it should be a comparatively simple matter to construe the lineaments of the moon. Such, however, has not proved to be the case. In round numbers the moon is only 240,000 miles from us, and has a diameter of 2163 miles, being a fraction over half that of Mars. When viewed through a telescope of about 400 diameters (which is found by experience to be the most satisfactory, everything considered), it is possible to perceive, though as a mere point, any feature upon its surface as large as an ordinary city block.

There are two peculiarities about the moon which have puzzled astronomers beyond measure and which until the initial appearance of this work, in 1912, had escaped their true solution. One of these is that it presents only one side toward us, and the other, that its topography appears to be so abnormally volcanic in character.

## *PROBLEM OF THE MOON'S MOTION*

It is truly singular that axial rotation, the cause whereof savants have never yet managed to guess, has been assumed to be the *natural* thing, whereas a condition of inertness and stability is all their dynamical premises give them the right to expect. So far as we know, Mercury (the smallest of the planets) and the only satellites of other planets susceptible of sufficiently definite telescopic examination (namely, some of Jupiter's) exhibit the same idiosyncrasy of motion as does the moon. It is positively unthinkable that such a uniformity of rotation can be the result of mere chance; but, on the contrary, it must be due, not only to a similarity of causes, but to such causes as inevitably lead to the one result. Astronomers have invariably approached this problem by assuming initial rapid rotations (not attempting to explain *them*) and thence toning these down, with their imaginary tidal brakes, to fit the observations.

As a matter of fact, the moon doesn't rotate on its axis in any true sense; that is to say, it hasn't an *inherent* motion of that character, any more than a balloon could be said to have were it also to circumnavigate our globe. Not having any fluid oceans, our satellite has simply settled into a position of stable equilibrium, ballast down, on the familiar principle of the loaded die.

In this attitude the moon makes a circuit about the earth every 27-½ days, the plane of its orbit being approximately the same as that of the earth's round the sun, so that we have what are known as *lunar phases.*

Now, the moon has a peculiar trick, in rounding from full to last quarter, of seeming to turn gently to the east so as to hide a part of that edge and simultaneously expose an equal segment or crescent around the *westerly* limb. After passing the quarter, the body swings just as gradually backward until at "new". Were it then visible, we should see its face precisely as it is at full. In the latter half of its circuit the same maneuver is repeated, except that there we get to see an extra crescent around the other, or *easterly,* edge. This phenomenon is what is known as the "longitudinal libration".

In order to solve this peculiarity it will be necessary to mention another fact or two by way of preliminary. The gravitational attraction of the sun on the moon, after all allowances as to distances are made, is a little more than twice that of the earth. Hence it may be asked why the moon does not settle with its center of gravity turned *sun*ward instead of *earth*ward, in which case it would show every side of itself to us, but keep one side perpetually directed toward the sun. The answer to this is not difficult. The test is not one of degree of power alone, but of *differentiation* of power. For the sun being some 400 times more distant than the earth, the angle formed by two lines drawn from his center to the two points marking respectively the center of figure and the center of gravity of the moon (for the two are by no means identical) will be only 1/400 as great as a similar angle formed by lines so drawn from the earth's center. Hence the sun cannot bring his greater strength so well to bear. It is a question of leverage, or *twist*. Now, as the moon progresses in her orbit she keeps shifting her angular position relatively to these rival attractions of sun and earth, and this it is that produces the libration in question. Thus, when she is at new, and again at full, the sun and earth act along the same straight line, but when she is at the quarters their attractions conflict most, and the moon swings east or west accordingly.

Here there arises an interesting problem on which we may now gain some light: How far would the moon need to be removed from the earth toward the sun in order to convert her from a satellite of the earth into a primary planet? As matters stand, when the moon passes *between* the other two, her motion is relatively *retrograde* with reference to the sun, but *direct* with reference to the earth. To *effect the conversion, then, from satellite into planet, she must exactly reverse this order of motion*—a process which obviously would not take effect spasmodically but by infinitely slow degrees, and during which she would gradually become more and more distinctly "retrograde" in character. In order for the sun to succeed in "wrenching" the earth and moon apart in this way, his leverage on the moon must, of course, be increased relatively to that of the earth, and as leverage varies inversely with distance, we easily perceive that the moon will become a planet when

$$\frac{M}{D^3} > \frac{m}{d^3}$$

in which M represents the mass of the sun, D his lunar distance; and $m$ and $d$ the mass and lunar distance of our earth respectively. Substituting the known values for M, D, and $m$ and performing the operation, we obtain for the value of $d$, 1,330,000 miles.

In a former chapter I explained how the earth and moon together are kept revolving around the sun by the action of the Prime Resultant, so that, including it, we have three rival forces continually pulling at the moon, all together being capable of accounting from instant to instant for all her varying movements. If, now, to these were added an inherent *arbitrary* rotation, as predicated by current theory, it is plain that the moon's safety would be imperilled. Like a weather vane she has to be, and she is, free to respond automatically to the eddying currents continually playing upon her, only in this case the "currents" are gravitational instead of atmospheric in their nature.

## *PROBLEM OF THE LUNAR SURFACE*

Generally speaking, the moon has a mottled appearance, consisting of great drab splotches on a silver shield. In Galileo's lifetime, and for many years afterward, these splotches were looked upon as seas, and they are still so called by the Latin equivalent, *maria.* However, they are no longer regarded by scientists in this light, owing to the fact that the improvement of the telescope long ago revealed many permanent markings on the beds of the supposed oceans which, of course, could not exist on a liquid surface. In addition to this ocular evidence that the term maria is a misnomer, observers of the satellite unanimously certify that they have never been able to discover any rain clouds in the lunar atmosphere. Indeed, even in this matter of atmosphere the moon appears to be no less destitute, the proof whereof consists in the circumstance that when stars are occulted by her, as occasionally happens, they disappear and reappear *suddenly* without exhibiting any signs of atmospheric refraction.

This poverty of the moon in water and air may be due to one of four reasons; first, to a scantiness in the original endowment of the body in these two elements, or, second, to the subsequent escape of their swifter molecules, as suggested by Doctor Stoney, or, third, to percolation and absorption into the moon's interior, or, fourth, to *transformation into another state or substance whereby they have become masked and unrecognizable.* Of these four hypotheses, it seems, contemporary scientists have finally settled upon the second as the nearest approximation to the truth yet proposed (though still admittedly far from satisfactory) while the last, and, as I hold, the true one, seems never heretofore even to have been thought of, much less discussed.

The most remarkable thing about the strange markings on the lunar ocean beds is not the fact of their existence, nor even the peculiarity of their shapes, but the singular *resemblance* which they bear to the extraordinary structures that exist in such profusion on the *continental areas. The same forces that modeled the first class must have unquestionably modeled the second,* The only substantial difference between the two orders is one of scale, those on the continents vastly exceeding the others in height; although there exists this minor distinction, that the configurations occupying the bottoms exhibit more of a ruinous appearance.

Compared to the earth's, the lunar surface is ever so much rougher, and these roughnesses differ so fundamentally in their general character as to compel the conviction that *they owe themselves to radically different modeling forces.* Let us, if you please, examine some of the principal of these

## CHARACTERISTIC LUNAR SURFACE FEATURES

CRATERS. Undoubtedly the most striking of these features is what is known as the *craters,* a name derived from their likeness to the mouths of terrestrial volcanoes, —a resemblance, however, that is only skin deep, and means nothing. To make out the general contour of these peculiar figures, no higher telescopic power is required than Galileo had available, and the probability is that with his first glance through the instrument he interpreted them as indeed volcanic; and that interpretation is the one which, in spite of later arrivals, commands the largest following to this day. The only other hypothesis that may be said to have gained anything like general acceptance among professional astronomers is that formulated by Professor G. K. Gilbert, in 1892, and known as the *Bolide* or *Impact* theory, which holds that the Craters are the pit holes made by the blows of fallen meteorites.

These lunar craters vary incredibly in size, ranging as they do from more than a hundred miles in diameter down to a size hardly perceptible through the best telescopes; indicating clearly that, for aught we can say, they may exist even as narrow as a few feet, or even a few inches; which is what I claim to be *actually the case.* In the multiplicity of their visible number these craters are no less remarkable, running literally into the thousands; and they are, also, amazingly diversified as well—yet, for all that, there is no mistaking their general kinship. This latter consists in two things, namely, that they all possess a surrounding wall or circumvallation, and, second, that the land craters are bolder in relief and more sharply outlined than their squat brethren on the maria floors. To all intents and purposes, indeed, the maria themselves are indistinguishable from the craters, save in the one particular of *size.*

Their individual differences, however, are legion. In some craters the encompassing walls are as much as four or five miles in height, while in others, even of very large ground plan, the rampart is scarcely tall enough to be distinguishable; in some the enclosed plain is as level as a floor, in others it is studded with cones whose peaks rise as high as the rampart itself; in some the wall is practically complete and of fairly uniform height, while in the case of a near neighbor the very reverse may be the case. In those craters where the walls are very tall, they are *terraced* on the inside, while, in those whose ramparts are low, or of moderate altitude, the inside wall is usually sharply precipitous. There are not a few instances where two, or even several, crater walls impinge, and one appears to mount higher on the ruins of the other or others. On the other hand, there are some isolated craters that have great breaches in their bastions, *breaches that cleave clear down to the ground and continue thence as canyons for scores and hundreds of miles through a most rugged country,* not following the valleys, mark you, but *straight through the highest mountains.*

Yet, though all the foregoing enumerated details are severally of great importance, and should be rehearsed by the conscientious student with attentive care, the two most significant, because *explicatory,* facts about these craters are, first, that *the deeper the crater* the more does the bottom of its pit extend down *below the general level of the surface,* much as though some giant had dug out a well and piled the excavated earth around the brim, thereby making the shaft doubly deep; and, second, that, steep as may be the inner wall, the outer invariably slopes gently away to nothing, unless some obviously independent formation rises to obstruct its normal trend.

WHITE RAYS. "The most puzzling feature of the surface", says Professor E. W. Brown (*Americana*), "consists in a series of white rays or streaks which radiate from a few of the principal craters in every direction. In their brightness they mask all other shades of tint on the surface and seem to continue their course, sometimes for hundreds of miles, quite independently of the nature of the country they cross. Professor W. H. Pickering, however, who has studied the systems carefully, considers that their actual length has been much exaggerated and believes that the apparent length is due to lines of small craters from which they emerge. The most remarkable system is that starting from the crater Tycho, itself of a brilliant whiteness, and giving the whole region the appearance of a globe cracked by internal pressure—a suggestion made by Nasmyth, who actually cracked a glass globe in this way and obtained a striking resemblance''.

SEAS. Of these the same writer says, ''The so-called seas of the moon are simply portions of the surface darker in color than the average and very much less broken up by craters or mountain ranges. These form the main features of the face seen at full moon. They are crossed by thin lines known as rills or clefts which run in all directions, sometimes straight and unbroken for hundreds of miles, even intersecting ranges of mountains and craters and reappearing on the other side. These rills are generally two and rarely exceed ten miles in width, their depth varying from 100 yards up. A curious feature of a different kind is an absolutely straight cut—the great Alpine valley—some 83 miles long, which crosses a range of mountains and under low magnification looks as if some wandering celestial body had grazed the surface''.

MOUNTAINS. These are described in the classical work of Nasmyth and Carpenter (*The Moon,* Chap. X) in these words, which I would ask the reader to study carefully in preparation for the explanation presently to be offered:

> In turning our attention to these features [mountain ranges, peaks, and hillchains] we are at the outset struck with the paucity on the lunar surface of extensive mountain systems as compared with its richness in respect of crateral formations, and a field of speculation is opened by the recognition of the remarkable contrast which the moon thus presents to the earth, where mountain ranges are the rule and craters like the lunar ones are decidedly exceptional. Another conspicuous but inexplicable fact is that the most important ranges upon the moon occur in the northern half of the visible hemisphere where the craters are fewest and the comparatively featureless districts termed seas are found. The finest range is that named after our Appennines. It extends for

about 450 miles and has been estimated to contain 3000 peaks, one of which—Mount Huyghens—attains the altitude of 18,000 feet. * * * Another considerable range is the Alps situated between the Caucasus and the crater Plato. It contains 700 peaked mountains and is remarkable for its immense valley 180 miles long and about 5 broad that cuts it with seeming artificial straightness and that, were it not for the flatness of its bottom, might set one speculating upon the probability of some extraneous body having rushed by the moon at an enormous velocity, gouging the surface tangentially at this point and cutting a channel through the impeding mass of mountains. * * * At first thought it might appear that the great mountain ranges were produced by bodily upthrustings of the crust of the moon by some sub-surface convulsions. But such an explanation could hardly hold in relation to the isolated peaks, for it is difficult, if not impossible, to conceive that these abrupt mountains, almost resembling a sugarloaf in steepness, could have been protruded *en masse* through a smooth region of the crust. * * * We believe they may be regarded as true mountains of exudation, produced by the comparatively gentle oozing of lava from a small orifice and its solidification around it, the vent, however, remaining open and the summit or discharging orifice continually rising with the growth of the mountains.

## LUNAR SURFACE CHANGES

The reader, I trust, recognizes the impossibility of discussing in detail the multitudinous data on this subject of lunar changes in the short space of a single chapter, and I shall therefore compress what must here be said in the narrowest possible space. To give him, therefore, the most information on this fascinating subject in the fewest and clearest of words,I shall quote,—rather disconnectedly, I regret,—from Professor Pickering's invaluable contributions as they have recently appeared in *Popular Astronomy* (Nos. 219, 223, 237, 238) to which the interested reader is earnestly referred:

The writer feels the lack of a generally recognized nomenclature to designate certain features upon the moon, particularly those areas of considerable size which darken with the approach of the lunar summer, that is towards lunar noon, and fade out again in the lunar autumn, that is towards sunset. They correspond to the Martian "seas", but since that term is already in use on the moon for other and much larger objects, he suggests the term "fields", which has the incidental advantage over "canals", etc., of indicating what is really meant, that is plains or slopes covered with some form of vegetation. * * *

The barren and unchanging region to the south of the crater will be referred to as the "mare". The brightness of two other regions has been (estimated), the "floor" and the "inner field". The latter refers to that small portion of the inner slope of the crater lying directly between the "source", or point from which the canals originate, and the crater floor. This region changes very notably in shape as the lunation progresses. Between the "field" and the crater lies a bright triangular area which contains several more or less variable canals. Indeed, nearly all of the small dark areas on the moon are variable under high illumination, when well seen, either in shape, or density, or both. Except in the case of a few small spots very near the equator, never has any variation been observed on the moon near the time of sunrise or sunset, that is to say near the terminator. * * *

Nearly everyone who looks at the moon through a telescope confines his attention exclusively to these regions, because they furnish striking views, are easily identified, and because what is seen is easy to understand. It is largely due to this fact that the impression that the moon is lifeless has so long maintained its existence, in spite of the facts to the contrary. The only time when the moon is interesting to one who is really used to its surface, is when changes are taking place upon it, and these only occur far from the terminator, that is during the lunar summer time. Then they are conspicuous all over the surface to any who will take the trouble to watch and to study them carefully. * *

At colongitude 30° each of the outer canals fork, but the four branches are very faint. The next day they reach their maximum length of 24 miles from source to terminus. Besides the two main canals others are seen in the immediate vicinity. In the dark region just outside the crater they are seen branching in all directions giving somewhat the effect of a country road map. In places one could scarcely travel three miles without crossing one. They are of all degrees of faintness from that of the two main canals already described, down to the extreme limit of visibility. The narrowest visible, however, can hardly be less than 200 feet in width.

The lunar atmosphere is very possibly considerably more dense than is generally supposed. We know but little about the refractive powers of very rarefied atmospheres when the mean free path of the molecule is of appreciable length. It is not likely however that its density exceeds a few milliimeters, and in that case ice when warmed would pass directly into vapor without passing through the liquid form. However tempting the idea might be, and their appearance certainly suggests it, these canals cannot therefore be irrigating channels either natural or artificial. * * *

In summarizing our observations it cannot be impressed too strongly on the reader that neither the dark fields nor the canals owe their blackness to shadow. Shadows are most conspicuous at lunar sunrise and sunset, and are absolutely invisible at full moon. These markings are invisible at sunrise and sunset, and are most conspicuous at full moon. Since the outer canals are wholly invisible at sunrise, though the region is well shown, and the inner ones are similarly invisible at sunset, they cannot be due either to troughs or ridges. The blue black color of the fields and canals can only be due therefore to a discoloration of the surface, which develops alike on slopes and levels in the lunar summer, and is invisible in the spring and autumn. We know of no mineral which acts in this manner, and the only possible explanation therefore seems to be that it is due to a covering of vegetation.

Scarcely any professional astronomers look at the moon now-a-days; it is left wholly to amateurs. Many astronomers write text books on astronomy. New editions are constantly being brought out in which they repeat the well worn statement that the "moon is without air, water or vegetation." It is impossible for a single writer to make headway against such odds. Statements and facts relating to bodies like the moon and Mars, which few astronomers ever look at, make progress but slowly. This is because the text-book astronomers never read them, nor do they believe the observers, if they do. There are too many other things that they must read. * * *

The writer first began advocating the existence of vegetation on the moon a little over twenty years ago, and has been writing about it ever since. Other astronomers had suggested it before him, but for the last hundred years the matter has been somewhat in abeyance, the last prominent astronomer who strongly favored it being Sir William Herschel. The writer hopes that in another twenty years the idea will have gained some currency, but alone, without the help of others, it is hopeless to expect to accomplish much. * * *

In colongitude 55°.9, the whole eastern face (of Pico) is resplendent with freshly formed snow, yet not quite so brilliant as at the higher levels, perhaps because on the lower and steeper slopes small projections of rock more frequently interrupt the bright surface. * * *

An interesting phenomenon is exhibited at this colongitude, when spots *a* and *d* begin apparently to steam. In a few hours thick clouds of vapor are thrown off, especially from *d*, so that its outlines become very hazy, and quite different from its earlier and later appearance, and from the other spots about it. Its color becomes decidedly bluish, and the fog or mist in a thin transparent stream is swept off across the mare to the south, as indicated in Figure 9. The action becomes less violent about colongitude, 90°, and by 95° has ceased altogether, as a usual thing, although it was observed on one occasion at the base of *d* as a very faint haze as late as 115°. All the spots have occasionally been recorded as slightly hazy at about this time, but none of the others are at all comparable in this respect to *d*. At colongitude 76°.8 the ridges of Teneriffe have been recorded as steaming from end to end. In the meantime neighbouring bright spots were perfectly sharp and distinct. This steaming might be either a case of melting snow or of volcanic activity, the steam condensing into ice crystals and falling as snow. The writer rather favors the latter view, since the other spots do not exhibit it. * * *

That certain bright spots such as Linné are always hazy is well known. The peculiarity of Pico *d* is that it is hazy only at specified seasons on the moon, when other neighboring and similar spots are sharp. * * *

Turning now to quite a different type of formation, we find scattered over the moon's surface, but especially in the equatorial regions, a series of small craterlets whose interior walls under all illuminations are of dazzling brilliancy. The floors of the smaller ones are also bright. One of the best known of these is Mosting A, some 5 miles in diameter, 3000 feet deep, and situated in longitude 5°, latitude —3°. On January 27, 1915, at colongitude 56°.3 the shadows still showed within the crater, but had entirely cleared the center of the floor, which appeared of a uniform brilliant white, without detail. On March 19, 1913, 61°.0, a minute black dot was detected at the center, of less than half a mile in diameter. It was also observed Feburary 18, 1913, 66°.0. On January 28, 1915, 70°.1, the dot was clearly seen, was about a mile in diameter, and was of the same darkness as the region surrounding the crater. Accompanying the dot, and reaching from it towards the north, three-quarters of the way up to the rim, was a faint dark band one mile in breadth. * * *

The point of first interest perhaps in this investigation is to find when the spots reach their minimum size. Within the craters, the dark areas appear and disappear at about the same interval before and after midday, which therefore seems to be the time when the snow presents the smallest area. In the case of Linné, Professor Barnard and the writer agreed that the minimum occurred one terrestrial day after the lunar midday. * * * It would certainly be of interest to prepare a series of drawings of the craterlet near Littrow B, and determine when its minimum occurs. In the case of Linn and apparently also of Littrow, the white spot is invisible both at sunrise and sunset. Just why this should be so is not very clear, but it would seem to indicate that the moisture can only escape from the vent about midday, and that towards sunset it all evaporates. Towards noon the evaporation occurs before it can get far from the vent, hence the spot is smaller, although brighter at that time than earlier or later. * * *

In the case of the mountains, Pico, Pico B, and Straight Range, most of the white spots grow smaller the longer the sun shines on them. Those on the west side of the mountains, towards the rising sun, are of full brightness when the sun first strikes them. Those on the east do not deposit until the sun has been shining on the region for a day or two. It appears as if the ground some little way beneath the surface must be heated up before the moisture can escape. * * *

The writer has sometimes been asked, "What reason is there to believe that there is ice upon the moon?" The answer is: "For the same reason that we believe there is ice upon Mars, because the phenomena observed can be more readily explained that way than any other." Whether the ice is deposited upon the surface, or floats as minute crystals just above it, in the form of surface clouds or fog, is not yet clear, but it is believed it occurs in both forms. Where the boundaries are sharply defined, it lies upon the surface. Where the boundaries are indistinct and hazy, as for instance in the case of Linné it is still uncertain. In the case of the bright rays surrounding Tycho, it is thought the ice crystals are supported in the lunar atmosphere like those terrestrial cirrus clouds to which we give the name of mare's tails. * * *

The question whether water formerly existed upon the moon is larger quantities than at present is usually answered in the affirmative, but generally for wholly erroneous reasons. We often hear it stated that the so-called seas are simply old ocean bottoms,—a most improbable view. A casual examination of the lunar surface shows that they were formed at a period subsequent to the creation of the larger craters, since we find numerous of these craters partially ruined and dissolved in them, evidences of fusion being everywhere visible. The seas really owe their existence without doubt to extensive fissure eruptions, such as have occurred in past ages in India and in some of our North-western states. During this period extensive areas of the Moon's crust sank beneath the liquid surface and were dissolved in it, much as often occurs at the present time on a small scale in Kilauea, Hawaii. The bottoms of the great majority of the larger craters were also dissolved or softened at this time, indicating that the crust was thin. After this period was over, a second era of volcanic activity began. The craters produced, however, were much smaller than those of the first period, and indeed are comparable in size to some of our own larger terrestrial craters. They are found chiefly upon the maria and smoother crater floors, and may be recognized by their dark color.

That there never was very much water on the moon's surface is rendered certain by the lack of extensive areas of erosion. Nothing is seen at all comparable in extent to what an outside observer would notice in inspecting the earth under similar circumstances. It is probable that all or nearly all of the large craters were originally furnished with central peaks, but in most cases these were destroyed when the floors were liquefied. Of the peaks which are left, doubtless all at one time, as in the case of our terrestrial volcanoes, gave out large quantities of steam and volcanic gases. On account of the rare lunar atmosphere, due to the small force of gravity, this moisture would have been immediately precipitated as rain or snow, so that the erosion would have been confined to, and concentrated about the vents.

In the lunar craters the only evidences of erosion are in fact found on these central peaks, but so marked is the effect in these places, that only a minority of the smooth cones of large size are left, while in the majority of cases we find that they have been partially cut, and sometimes almost completely worn away. * * *

It would seem as if there could be but little doubt that the brightest regions shown in these drawings owe their brilliancy to snow. In order to withstand the evaporation due to a tropical sun, unprotected by any appreciable atmosphere, in latitude 11°, this snow must be rather deep, even if it is being constantly renewed from the Moon's interior. It must be remembered that none of the bright lines shown can be less, allowing for irradiation, than 50 to 100 yards in width, and none of the circles much less than half a mile. In a rough and jagged region there would be many small steep areas where snow would not lie, but which would become visible to us only, on account of their small size, by a diminution of the general brilliancy of the whole area. We might naturally expect therefore that some snowy areas would appear to be brighter than others. * * *

A very casual examination of the Moon will show that under high illumination nearly half of the craters exhibit white patches on portions of their interior slopes. Very little attention has ever been paid to them by selenographers. They are sometimes visible as soon as the Sun rises upon them, but more often they gradually develop under the action of the solar rays. They lie on the slopes most directly exposed to the Sun, and as the

Sun moves across the lunar sky, they shift from the eastern to the western side of the craters. In the southern hemisphere they circle round the crater by way of the south, and in the northern by way of the north. Even quite near the equator the circling occurs to a certain extent. The whiteness is frequently due to small irregularly shaped bright areas, which are sometimes related to small craters, but more often they lie on some steeply inclined interior slope. They rarely occur on the outer slopes of the craters.

Let one more quotation suffice, this time from the article of Professor Russell W. Porter, entitled *Moonscapes* (*Pop. Astr.*, No. 238), which is embellished with three instructive ideal views of the moon that cannot be distinguished from Arctic landscapes, or rather snowscapes. He says:

> Our nearest neighbor, the moon, is a case in point. The writer, in viewing her surface through his sixteen inch reflector in the comfort of a closed observing room, has frequently caught himself transported to that body, and, in imagination, viewing her scenery from some crater lip or the vast expanse of one of her sea floors. Having himself spent many years above the Arctic Circle, he was struck by a strange likeness of the moon's general aspect to our own polar regions. The long reaches of the frozen polar ocean, traversed by immense pressure ridges and tidal cracks, the dazzling whiteness and clear cut shadows, the desolation and loneliness—all seemed to find a counterpart in the lunar appearance. The accompanying moonscapes were the natural outcome.

## CURRENT THEORIES REGARDING THE LUNAR SURFACE

THE PLUTONIC OR VOLCANIC THEORY. Since, in our superlatively practical age, we find astronomers, even those of an agnostic turn, ready to subscribe to such superstitions as uncaused motions, self-rotating nebulæ, and the like, it is easy to excuse Galileo and his contemporary sympathizers for accepting, out of hand, the preposterous notion that the so-called craters of the moon are veritably volcanic. But that such an infantile idea has been able to survive the discovery of the mechanical equivalent of heat and command at the present moment the confidence of the great majority of learned scientists, is to me one of the most cryptic of modern mysteries.

It is not a difficult matter to compute what the moon's temperature should have been at the close of the still-credited Laplacian cosmic process, and the calculation has been made thousands of times. Thus, Doctor Lowell, in his *Mars as the Abode of Life* (p. 23), says, "On the principle that the heat caused by contraction was as the body's mass, this state of things on the surface of our satellite is unaccountable. The moon should have a surface like a frozen sea, and it shows one that surpasses, the earth's in shagginess." His calculation, he reports, gives the satellite's temperature as only —27° F. "To point out that any volcanic action could be produced by this quantum of heat", he adds, "is superfluous". All this was long known to astronomers, without, however, in the least influencing their doctrinal teachings, and even before Darwin took a hand, with a view to helping matters, by ingeniously extracting the moon from the supposedly much hotter body of the earth.

It then came to be taught, and is still taught in all the main institutions of learning in this and other countries, that the numerosity and the monstrosity of the lunar craters is due to the happy combination of these two factors, namely, first, the possession by a small body of a cosmic temperature appropriate to one 80 times larger, and, second, a coincident reduction in the weight of substances; the former factor supplying the desired augmentation of the eruptive forces behind the volcanic activities, and the latter accounting for the relatively farther distance to which the lighter-weight debris was driven. It was, in fact, somewhat analogous, in their minds, to the imaginary transplanting of a strong man from here to the moon, where his power to lift weights would be sextupled.

Struthiously shutting our eyes, as the astronomers here do, to all the *ifs* and *ands* by which this ingenious deduction has been arrived at, let us provisionally accept it as true and see how well or ill it fulfills the requirements.

In the first place, there is the planet Mars, which is midway in mass between the earth and moon, yet *not a* *single crater or, in fact, any protuberant irregularity at all* has yet been descried upon his surface! Judging from these two bodies, Mars and the moon, alone, then, we should naturally conclude that the smaller the cosmic body the more rugged. But proceeding another step higher, we find this rule already violated; for the earth is very much rougher than Mars, yet far less so than our satellite. Now, inasmuch as our Vulcanists are universally agreed in holding that our planet, too, is a shrinking body and that the asperities on her surface are due solely to this cause and the kindred cause of volcanic upheaval, it follows that the only salvation for the Volcanic hypothesis is to establish that the moon, when she gained her supposed separate existence, must have been far *hotter than Mars and at least as hot as the parturient earth.* In fine, the Vulcanists are logically *forced* to be Tidal-evolutionists, and their theory consequently rests on Darwin's admittedly "wild speculation impossible of verification".

Secondly, investigation has shown that the earth's temperature rises one degree for every sixty feet of depth, and it is only fair to presume that this rule held *relatively* true throughout her postulated contracting process. Judging by the existing gradient, the temperature at the earth's center should be about 320,000 degrees F. as against, say, 550°, absolute, near the surface. If, now, we conceive the earth to be divided into 81 concentric strata, all of them of equal mass, the *temperature of the outermost should average only that degree marking the middle of its thickness, or,* by calculation, 1250° F., abs., while the average temperature for the entire planet should be no less than 80,000 degrees! Now, Darwin's idea was not that the moon was explosively ejected out of the *heart* of the earth, but that she was *flung* off from its *periphery* by centrifugal force. Had the former act been postulated, it would be good logic to say that she bore with her the average temperature of the planet, but inasmuch as she was flung off from the outside, her hotness could not have been greater than that of the crust, the very coldest part of the planet, and *theoretically very* *little above what the satellite should have possessed had she separately agglomerated!*

Finally, to cut short a long list of criticisms, it is not true that, even had the moon originally possessed the same temperature as the earth, her volcanic displays would have been more devastating in the ratio of six to one. The solar gravity is 27.6 times that of the earth and 165 times that of the moon, *yet he ejects matter at times as far above his photosphere as the moon is from the earth.* Anyone who has ever watched quarrymen at work knows that "tamping" is a very important part of the blasting process. A *heavier* charge *lightly* tamped will not begin to create as much havoc as a *lighter* one *well* tamped. Ramming the charge too tight has ruined many a good gun and robbed its owner of his life. *The heavier* the weight of the superincumbent materials the longer are the explosions delayed and the severer when they come.

The biggest crater on the earth is said to be that of Haleakla, Hawaii, possessing a diameter of less than seven miles; and there are not more than a half dozen terrestrial craters that could be made out by a lunar observer, though armed with our best telescopic instruments. On the moon, on the contrary, there are literally *thousands* such, a half dozen of the largest being upwards of a hundred miles in diameter, and thence dwindling to invisible sizes. To account for all these dynamically and adequately, Darwin should have accouched his moon from the sun, not from the earth; and she should have been as diminutive as Eros, besides.

THE BOLIDE THEORY. By way of an alternative hypothesis, Professor Grove K. Gilbert, whilom president of the Philosophical Society of Washington, in an address before that body in 1892, expounded the notion that the earth may primevally have possessed a ring like that of Saturn, and that the lunar asperities were produced by its collapse. The reader will find an excellent presentation of this view in *Popular Astronomy,* March, 1917, by Donald Putnam Beard, from which I quote:

ORIGIN. If we conceive the moon as an edifice which had its foundation in a ring or shoal of meteors encompassing the primeval earth, and similar to the giant planet Saturn (the meteoric constitution of whose rings was spectroscopically demonstrated by Keeler in 1895), and if we imagine this shoal gravitating together and building up our satellite by accretion, no violence is done the essential principles of Laplace's immortal Nebular Hypothesis. Meteors replace molecules, that is all, as long ago pointed out by the late C. A. Young. The mechanical behaviour of a meteor swarm containing individual masses and endowed with the ordinary velocities of meteors would be precisely similar to a nebulous mass of continuous gas.

The mathematical analysis of the mechanical conception of a Saturnian ring is not in place in a discussion of this nature, but by imparting to the postulated meteors in the swarm orbits not widely variant from that of the moon's, and in a similar direction, their initial velocities at impact were small as compared with those created by the moon alone. Since the course of these moonlets were parts of curved orbits with the moon at their focus, they cannot justly be considered as straight lines. By restricting these meteors to a thin plane ring, and assuming a fairly equable distribution through this plane, the distribution of impact angles deduced by Gilbert yields a curve in which 58 per cent deviate from the vertical less than 20°; 70 per cent less than 30°, while 80 per cent fall within 40° from the true vertical. To the vertical infalls consequent upon this condition is due the prevalent circularity of the craters and obviates a resort to R. A. Proctor's improbable suggestion of an elastic return to circularity.

Laboratory experiments with a lead disk 5.5 inches in diameter and about 0.5 inches thick as a target, into which .22 caliber bullets of the same material were fired, demonstrate experimentally the effects produced by the impacting moonlets upon the moon's surface. Interesting replicas of the moon's crater forms were thus obtained by the writer. * * *

OVERLAP. An instance in which a larger crater overlaps and partially obliterates an earlier and smaller formation is shown in Maurolycus, in the roughest portion of the moon. The observed fact that there are comparatively few of these examples is eagerly taken by the volcanic advocates as proof positive that the moon's craters are defunct volcanic formations. But the very paucity of instances, far from proving the truth of the vulcanists' contention, is mutely eloquent in our defense, since the probabilities would be overwhelmingly against the survival of this species of "overlap" crater. Yet this superposition of larger over smaller craters is exemplified by Longomontanus, Maurolycus, Hainzel, Schiller and others.

SCULPTURE. The peculiar plateau of Wargentin and Phoclydes are striking examples—in more than one sense—of some tremendous lava deluge. The first-named object is a smooth, nearly circular mesa 54 miles across and filled nearly to the level of the lowest point of its rim with solidified lava. That Wargentin does not reign alone in his unique grandeur is proclaimed by the partial filling of Gassendi, Letronne and Hippalus to the north; craters which experienced a community of origin with Wargentin and the neighbouring depressions.

As the result of moonlet impacts in the adjacent maria and the fall of lithic dust from their conflagrations, Boscovich is scarcely to be recognized as a crater, while Julius Caesar and LeMonnier have nearly lost their characters. To the vaporization of the more massive bodies the many "ghost craters" on the moon owe their partial effacement, typified by Fra Mauro, Fracastorius and Cassini. As Doctor See wrote concerning these dim spectres of the desolate lunar Hades: "So far as one can see, only two explanations are tenable: 1. The deposit of cosmical dust from the heavens, and from conflagrations arising in the impact of satellites. 2. The partial melting down of the walls by the conflagrations which produced the maria, so that only an outline of the original crater walls can be traced."

The southern boundaries of the great Imbrian lava deluge visioned forth as occurring far down the vista of the ages were determined by Pitatus and Hippalus, while southwestward the onslaught of the impacting planetoid's molten flood attained Posidonius and eastward it lost itself in the Oceanus Procellarum. By this memorable world-wide cataclysm, which at one stroke wrought the Maria Imbrium, Nubium and Humorum and the encricling ramparts known as the Apennine and Caucasus ranges, "were introduced the features necessary to a broad classification of the lunar surface."

LUNAR "VALLEYS". A veritable "Valley of the Moon" is the Rheita Valley. This is a shallow groove of varying width with a shorter off-shoot on the south end. It runs from the eastern edge of the crater Rheita southwestward more than 185 miles to Rheita *d;* its breadth varies from 11 to 25 miles, with a maximum depth, according to Beer and Madler, of about 11,000 feet. A long, narrow cleft resembling a rill, starts from near Piccolomini and trends southwestward more than 450 miles to near Metius, which temporarily interrupts it; but it continues its course beyond that crater and to the right of the Rheita Valley.

However, the Alps Valley, a straight defile traversing the lunar Alps range, is the most interesting of them all, betraying an exceptional character which demands for its origin an exceptional explanation. A trough-like flat-bottomed groove trending east-north-east by west-south-west clean across the Alps range;

it is 83 miles long by from three and one-half to six miles in width, and from its positioning bespeaks kinship to the Imbrian deluge, thus uniting the furrow group of the western district with the eastern sculpture system.

BRIGHT RAYS. The system of brilliant rays which radiate from the crater Tycho down the lunar disk, like luminous parallels of longitude, and also the wavy streaks converging upon Copernicus; the lesser systems of Proclus, Kepler and Snellius, are the most enigmatic phenomena of the moon's surface. Those emanating from Tycho extend for vast distances across the lunar disk; in one instance— that of the one crossing the Mare Serenitatis—near 18,000 miles. Straight as the famed canals of the desert planet Mars, they seem not to mind obstructing craters or elevations in their predetermined path. As a contrast, those radiating from Copernicus are branched and wavy and much shorter than the Tychonic phenomenon. * * *

Most conspicuous at full moon, under the vertical solar illumination, they seem to be superficial colour-streaks only, and one can be seen on the inner floor of Saussure, near Tycho, and may even be traced up its inner cliffs, like a vein of volcanic trap piercing sedimentary rock-strata on our own planet. This is a treacherous analogy, however, as Mr. R. S. Tozer has pointed out. "The lowest visible stratum on the moon is dark, the configuration of the edges of the light coloured portion showing plainly that the darker portions extend underneath. * * * Whence, then, the light coloured lava?

These brilliant rays cannot be inner material extruded from beneath a crust rent by tidal stresses, since an exact restoration of level which would not cast shadows at sunrise or sunset along hundreds of miles would be practically impossible. But the suggestion advanced by Mr. William Wurdemann of Washington, D. C., seems more plausible; viz., that "a meteorite, striking the moon with great force, spattered some whitish material in various directions." Furthermore, Professor Gilbert, in the lecture previously adverted to, made the prophetic suggestion that "perhaps the free iron and nickel of meteorites may stand sponsor for free sulphur or phosphorus in moonlets."

When astronomers undertake to theorize, there appears to be no limit to the violence of the assumptions they permit themselves. Because one planet out of eight, Saturn, has a ring, it is taken for granted that the earth had one, and a fantastic hypothesis is straightway built upon the gratuitous idea. No one seems to ask, or care, whether the *size* of the planet can have any bearing on the matter, or whether the distance and measurements of the ring are conditioned in any way, or whether the sizes of its component particles are minutely limited by a natural law, or how such rings come into existence, or how, in collapsing, they do so upon *themselves* instead of upon their primary, *or how they can collapse at all under the Newtonian traditions.* The exterior diameter of Saturn's ring is only 173,000 miles, whereas the diameter of the moon's orbit is 480,000 miles—almost three times as great; nor is there any sign in *his* ring of any considerable nucleus comparable in magnitude to our moon. Should anyone suggest that the disintegration of such a structure would result in the creation of another Saturnian satellite instead of a meteoric shower upon that planet, he would deservedly be looked upon askance.

About the only characteristic marks on the moon's surface that this impact theory even remotely fits is the simple lunar crater, not *all* the craters, but only that sort of crater that exhibits a small *shallow* pit *without central cones.* It does not explain the *depression of the pit floors* below the general level of the surface, or why some of the craters biggest in diamter have quite low ramparts and exhibit no inner depressions worth mentioning. It does not explain the *inner terraces*, nor the *non-destruction* of the existing central cones, nor the strange coincidence of groups of small craters huddled within the enclosures of some of the larger ones. Nor does it explain the remarkable phenomena of sugar-loaf mountains, the *stupendousness* of the Apennine range, the strange *immunity from petty bombardment* of the vast areas called maria, the wonderful chain of *bluffs* hemming in the maria, the several-hundred-miles-long ravines, and the like. Least of all does it account for the thousand and one *diurnal variations in the map and color of the moon,* of which, thanks to such keen and conscientious observers as Professor Pickering, the recorded evidence is rapidly accumulating—since the first edition of this book appeared.

## THE MOON'S TOPOGRAPHY EXPLAINED

Paradoxical as it may sound, the *real* surface of the moon *is as smooth as that of Mars!* Equally paradoxical may ring the statement that the lunar oceans have risen from their beds and taken up their permanent abode on the dry land. In plain English, they have disappeared, not into outer space, but into SNOW, *and the mountains and craters that we see are nothing more nor less than the fantastic sculpturings of one Jack Frost.* Like the man in the fable who could not see the woods for the trees, so astronomers have been all along failing to see the lunar oceans because of the heaped-up snow! The text books tell us that snowflakes are so exceedingly porous, and absorb so much air in their creation, that a single inch of rainfall is equivalent to a *ten*-inch fall of snow. Fancy, if you please, some strange freak of Nature whereby all the waters of *our* oceans and rivers and lakes should be converted into the "beautiful" and settle upon our continents and islands never to return again as water to its ancient beds, what a wonderful and strange sight our earth would present!

*This is precisely what has happened to our moon.* This is why her surface is so magnificently sculptured, why we see no rain-clouds or oceans upon her, why her atmosphere has "disappeared"—why, in short, she presents the curious aspect and asperities she does.

Here you may interpose, "Then how do you account for the fact that the same sort of thing hasn't happened to the earth and Mars?" Easily enough. With respect to the sun, the moon does not rotate on her axis in just the same way as she does with respect to the earth, but turns completely round, so that every point on her surface experiences a day one of our fortnights long followed by a night of equal length. In short, her days and nights are virtually two *seasons*, summer and winter. This strange arrangement, as you can see, accentuates many fold the *contrast* between the seasons, and causes us to ruminate how the thing works out. We have only to use our eyes —and brains—to satisfy ourselves.

By analogy, we are bound to presume that the moon possesses, or at one time did possess, oceans in about the same ratio to her mass as the earth, Mars and Venus. It is true this is only a presumption; nevertheless it places the burden of proof on those who assert the opposite. The question then confronts us; What effect should these lunar changes of season naturally have on the waters of her streams and oceans? That these would undergo great evaporation under a steady stream of sunshine two weeks on end goes without saying, even were the moon's gravity as great as the earth's, *a fortiori* in that her gravity is but 1-6 as strong.

The next question is; Would the two seasons evenly counter-balance each other, so that the summer's warmth would *completely* counteract and undo the gelid effects of the preceding winter? This question is not one for argument, but for objective fact, and *the moon's visibly glacial condition is the answer.* We have only to suppose that at the beginning of the process, whenever that may have been, *the first winter deposited a greater litter of snow than the ensuing summer succeeded in clearing away,* so that a residual sheet of snow—how large is immaterial, seeing that time was not of the essence—remained at the end of the first day (or summer) as the nucleus for later accumulations to come. Thus, day by day, *with accelerated growth,* the store of snow and ice accumulated until *all* the water was congealed and all that the winters had thereafter to do was to keep up the status by merely making good the day's inroads.

Of course, we cannot see the changes taking place on the dark or hidden side of the satellite, but we can easily judge of them from what we can perceive going on on the areas we do see; and these latter are so easily understandable that a formal interpretation ought scarcely to be required here. However, they are so interesting in themselves that we shall consider some of them, by way of illustration, to show how simply to construe even the most complicated formations are.

MARIA. These are really ancient ocean bowls from which their whilom contents have taken flight in the form of white flakes, which, settling on the *dry* surfaces, have made these their permanent abode. Owing to the geometrical fact that the areas of small spheres are, relatively to their mass, larger than in larger spheres, the oceans of the moon were proportionally shallower, averaging, in fact, only about a half mile in depth. As the levels in these receded because of the snow exodus, naturally the protuberances (of uneven height) on the bottom became successively exposed with lapse of time, creating new islands and *new resting places* for the flakes. Now, it is self-evident that the nearer the pinnacles of these originally submerged protuberances lay to the surface of the sea, *the sooner would they have become exposed* and *the sooner would the flakes begin building upon them;* but it is also true that, unlike on land surfaces, such sub-aqueous irregularities are the exception rather than the rule, hence snow mounds on the sea-beds should not only be lesser in magnitude, but *fewer in number.*

Inasmuch as, according to our premiss, there was never a let-up to this peculiar process of ocean-robbing, the time eventually arrived when the entire floor became virtually uncovered, presenting in reality a *land* scene in which every bar and sink-hole showed—save, however, that on all the emerged spots there rested columns of snow, more or less squat, and that the sink-holes were normally empty. I say *normally* empty advisedly, for the reason that during the hot season, as we can see today, a good deal of the snow naturally thaws again and trickles down into the lowest places, forming there *black pools* which contrast vividly with the scant vestiges of snow that may be found in these recurrently flooded regions. Between the blackness of such pools, however, and driven snow, there are, of course, all gradations of white—though *no colors*—to be seen. These diverse shades are due to one, or to the combination, of two causes; first, to the soaking of low-lying snow as a result of thawing, and, second, to a seaming and corrugating of other snow surfaces, especially on slopes, by irregular thawing, slipping, and settling; *the dense shadows of the ridges in the furrows marring the general brightness.*

It would be unreasonable for us to expect to find on *our* ocean beds, could they be revealed to our eyes, the same perfection and profuse diversity of configurations that our land surfaces exhibit, and the same thing is true of the lunar maria. These tell us just what they are. The "ruined" mounds, craters, and other structures we there see are merely the abortive efforts of the Ice King *when his supply of raw material had about given out.* Apropos of this, I cannot forbear to quote the lucid impressions of an amateur astronomer, Mr. John A. Cook, as set forth in *Popular Astronomy* (No. 235):

> For more than thirty years I have been studying and observing the Lunar surface in an amateurish way, using instruments ranging in size from two to ten inches, and have arrived at conclusions at variance with those, so far as I know, held by the great selenographers, living and dead, regarding the above mentioned features.
>
> We find them scattered about over the floors and shores of the Ocean and seas. When found fully down on the sea floor they often present but the merest trace of a ring. Those on the shore will show that part down in the sea destroyed, while that portion of the crater on higher ground is intact.
>
> Writers speak of them as Ruined walls, Submerged walls, Melted walls, and often as destroyed by some unknown cause.
>
> I have searched the works of Neison, Pickering, Elgar, Lohrmann, Fauth, Nasmyth & Carpenter, Serviss and a host of other more general works to find if some one would not suggest water erosion, and if not why not, to account for their ruined condition, but have failed. The opinion seems to prevail that they have been submerged, inundated by molten matter welling up from the interior burying them. As this would require material enough to spread over between two and three millions of square miles, and to a depth of more than a mile, and as we find no trace of such a lava outflow except in the seas, if there, I find it difficult to accept the theory, even with my great respect for the above named masters of selenography.

CRATERS. The flatness of Mars, a larger body, indicates that the moon should be essentially fully as flat, *if not more so.* Such a land surface, we know from daily observation, is ordinarily exceedingly cut up by channels into all sorts of irregular islands and peninsulas, diversified by equally miscellaneous small expanses of water of varying depth. Let us pick out, to begin with, a large lake of considerable depth and possessing a smooth floor, and question ourselves what sort of a snow structure would be likely to result were the water to be set to boiling on the coldest day of an Arctic winter. The rising vapor would, as a matter of course, meeting the icy air, transform itself into snow, and, unless driven far by winds, descend and settle on the nearest land, namely, the margins of the lake, where they would continue to build themselves up as long as there was neighboring water being evaporated. Of course, a good deal of the snow would fall back upon the water, but there *it could not lie,* unless, indeed, the lake froze over, which, in turn, would mean the cessation of the chain. But let the process continue until the lake went dry, what shall we then have? Surely nothing else but a *simple lunar crater*—a *cavity hollowed out of the earth surrounded by a solid wall of white.*

If instead of a single lake, you will imagine another one adjoining it, and much deeper, you will find at the end of the operation one *complete* wall encircling the second or deeper lake *encroaching upon and "ruining" the wall of the first.* Let there be an island or islands in the lakes, and you will have examples of a *peak* or *peaks,* whose thickness and height will depend in large measure upon whether they were originally submerged, and if so to what depth.

Just as there may be *peaks within craters* so there may be *craters within craters.* The difference consists in this, that whereas the peaks are solid columns mounted on islands from snow supplied by the vapors risen from *surrounding* pools, the craters are *hollow chimneys* grounded upon the margins of *enclosed* wells sunken into the floor of the main basin. That is to say, some pools, both large and small, when baled out, exhibit not only protuberances on their floors, but also pit holes that still remain filled with water, and these sub-pools by going through the same *modus operandi* as did the original one give birth to *sub-craters.* In fine, every dent in the moon's surface that normally would be filled with water becomes a crater by the conversion of its contents into snow flakes and the settling of the latter on the brims.

The *very largest craters on the moon are, literally, the maria themselves,* for here was the chief source of the snow supply. Around their borders on all sides, therefore, stand high snow cliffs, some of them very precipitous; while at other places there are terraces, or perhaps gentle slopes masking the elevated character of the mesas or plateaus at their backs. These differences are due to the varying natural depth of the ocean bed at the shore line. If the offset is abrupt, the gathering water from the summer thaws washes and undermines the base of the glacial cliffs, keeping them sharply trimmed, whereas if there is a natural beach, a different order prevails.

When snow is piled too high, its own weight causes it to collapse or telescope upon itself, resulting in two things; first, the top layer flattens out and overhangs the base, forming a lip, which in time loses its balance and falls, forming a terrace or talus; this event being perhaps followed by another similar avalanche farther on, provided the pile be sufficiently deep; and, secondly, the increased weight finally reaches an *extreme limit,* where it liquefies and squashes out the undermost layer into the flanking pools. These two processes, major though they are, are yet beyond the range of our telescopes to reveal and rest solely upon deduction. Taken in connection with the continuous repair work being performed by the ever-rising snow, they suffice to keep the lunar structures looking remarkably clean-cut and permanent, a circumstance which has led astronomers into the erroneous belief that there is an absence of "weathering" on the moon.

When the process of glaciation originally began, the lunar atmosphere was, of course, very much denser than it is now, because the snow-that-was-to-be had not yet absorbed it. As a consequence, the meteorological conditions at the outset were much different from now, for whereas the winds doubtless then played a strong role in scattering the snows far and wide over the continental plains, these snows are now quiescently restricted to the immediate neighborhood of the ancient pools, accentuating thus the magnitudes and salient features of the lunar sculpturings, more particularly of the craters, at the expense of the inland prairies.

In elucidating a general principle it is usually much simpler and more satisfactory to choose a concrete example. Let us picture to ourselves, therefore, a circular cistern twelve feet in depth and a hundred feet in diameter. Instead of the walls being vertical, however, let us imagine them sloping downward toward the center of the bottom, but so as to leave a circular flat space, say 25 feet in diameter. Now, for the sake of easy reference, conceive of this slope as cut into four steps, each a yard in height. We shall then have a structure resembling the pit of a Roman amphitheater. Again, let us picture standing on the bottom a number of granite blocks respectively 2, 4, 8 and 10 feet in height, to represent natural protuberances. Let us now fill the cistern to the brim with water, thus submerging all the blocks, and start the natural process of evaporation and snowing, limiting at the same time the snowfall radius to, say, a thousand feet; for we must not overlook the present quiescence of the moon's atmosphere, on account of which the snow spreads but slightly.

Now, until the water in the cistern has evaporated down to the level of the first tread (beginning from the top), the falling snow cannot gain a footing on the water surface, but must settle only on the brim and a slight distance beyond, its depth gradually decreasing to our prescribed snowfall limit. A yard's depth of water, area for area, being equivalent to *ten* times that heighth of snow, we shall have gained by the evaporation of the first yard a snow rampart all around the brim, say five feet high, sloping gradually backward to nothing. I have just stated that the snow could settle *only on the brim,* but this is not precisely true, for we must not forget the tallest of the granite blocks, which for one-third of this time has been exposed. It, too, is capped with snow, say to the depth of two feet.

Now suppose another equal period to elapse, and the cistern's depth reduced to the level of the second tread. This time the brim's cap has increased by another five feet in heighth, and the slope behind it in slightly less proportion, because the rising snow brim has in a measure further blocked the spread of the snow. Again, the first tread having all this time been clear of the water, it, too, is covered, and to a depth of five feet; the tallest granite island has also gained six more feet in height; and the second one of eight feet, having been above water two-thirds of the period, disports a snow cap of four feet. Thus the process goes on till we reach the circular area at the bottom. In this area we have finally four islands standing in a shallow pool of water less than a yard deep. But note that the first block uncovered is not the tallest now, for its pinnacle being, let us say, only two feet square, lacks the *area* necessary to sustain a taller column. As a matter of fact the third block has much the broadest top of any, and though still shorter than either the first or second, must in time, as the result of future processes of evaporation and snowfall, grow to a great height; yet, being itself limited in area also, it can perhaps never reach the altitude of the encircling rampart, which by now, let us say, has risen to the imposing altitude of possibly thirty feet, and will continue rising, given the necessary supply of snow, until it telescopes upon itself by its own weight. But to return to the moon:

Naturally, the melted water that manages to seep back into the basins must, *while the sun is still high,* immediately undergo again the process of evaporation. Owing, however, to the frigidity of the planet's quiescent atmosphere, as well as to its own self-built prison walls, the rising *mist changes into snow before it escapes from the caverns,* in which condition it is, of course, undetectable as *vapor.* Some of this snow doubtless spreads promiscuously over the planet's surface, but a major share of it remains to restore and heighten the old walls. This piling-up process cannot go on indefinitely without eventually causing the peaks to telescope upon themselves from time to time, partly on account of their own over-gorged weight, and partly because of the undermining of their bases by the periodical flooding of the bottoms. This telescoping process gives us the key to the *terraced* effect so generally observed on the inner sides of the crateral ramparts and supplies the reason for the otherwise surprising *precipitousness* of their faces. It also explains why the mountains and ramparts automatically preserve a *maximum uniformity of height,* and why the great ring-walls present their characteristic *squashy, convolute appearance.*

MOUNTAINS. Selenographers have in the past regarded as the most puzzling of all facts about the moon "the presence of the most important mountain ranges in the featureless districts termed seas, where the craters are fewest." By my hypothesis, the mystery becomes a mystery no longer. In the oceans, *when full,* there could not, of course, have been separate pools; hence no craters. But there were doubtless natural islands. These latter, situated as they were in the very heart of the snow-producing regions (these maria) accumulated the tremendous loads, that now mark them to us as "mountains".

The island of Cuba is 730 miles long, the lunar Appennines 450 miles. Imagine rapid changes of the seasons to occur on the earth as they do on the moon and that the snows from one winter to another would keep on accumulating until Cuba should be crowded with all the snow it would hold, what a wonderful mountain range would it not make—"in the midst of a featureless plain" —and how like to the lunar Apennines! As for the Valley of the same name, that is merely the vacant trough of the sound that originally separated the island from the mainland.

There would, however, be a great difference between the height of the Cuban range of snow mountains and the 30,000-foot Apennines, inasmuch as the surface gravity here is so much greater. The latter mountains are at their maximum possible height, for, *however much they may be snowed upon, they cannot grow taller, for the simple reason that their base becomes liquefied and runs out pari passu.* Now, snow is snow wherever it may be, and if piled on the island of Cuba would, other things equal, act as it does on the moon. Other things are *not* equal, however, particularly in this matter of the surface gravity, as just suggested; consequently our Cuban range could, automatically, never exceed a mile in altitude.

WHITE RAYS, RILLS, etc. Imagine, if you please, an immense marsh 500 miles or so in diameter irregularly cut up into all sorts of small patches of land separated from each other by narrow strips of water of varying depths, with here and there a larger expanse of land bearing small ponds or lakes; and picture to your mind's eye how such a scene would be transformed by such a process of glaciation as I have described. In such a case, soon after nightfall, every natural ledge of land, and every ledge that by the sun's evaporation had become uncovered, would again become decked with fresh snow, the depth varying, of course, according to the controlling circumstances. Indeed, twenty-four hours after the sun had disappeared below the horizon, and perhaps earlier, every square inch of the lunar landscape, every nook and cranny, including even the beds of all the streams, lakes and maria, would be covered with the mantle of white, and this state of things would continue unmodified all through the long night until close upon dawn. With dawn, however, would begin the great thaw, and the solar artist would occupy himself the ensuing day in etching out the land shapes by, at first, melting the snow where thinnest, which is to say, on the ancient water beds, and subsequently accentuating his artistic effects from hour to hour. In fine, the white rays are neither more nor less than the *persistent deeper deposits of snow piled on the broader and originally more elevated and receptive patches of the marsh land.*

The rills and "canals" are dried-up streams, connecting straits, or, in some cases, arms of the seas, that, should the snow all melt away entirely, would fill with water to the brim. The reason why they *never* fill up with *snow* is surely not hard to understand. Though the sun's heat may fail to bare the ground of snow *universally,* it is not said that he does not thaw great quantities of it away, or, even, that some of the land may not be periodically bared in exceptional places. The water from these thaws, like that from rain, *seeks its lowest level* and, as a matter of course, drains into the ancient channels and pools. Arriving there it dissolves what snow may have previously settled in them, or tumbled into them from the icy cliffs on either side, and then, being cornered, as it were, by the sun, it rapidly starts evaporating, and the vapor, changing promptly back into snow, settles down again and systematically restores the walls lining the banks.

Owing to the circumstance that the lunar atmosphere has now found burial in the snow mounds, there are no atmospheric storms on the satellite, and the freshly-formed snow does not scatter much but settles on the cliffs closest by. Wherever the natural stream or pool is *shallow,* therefore, the *lower* are the adjacent walls, and, conversely, the *deeper* these are *the more imposing the snow phalanxes hemming them in.* On this hypothesis, then, there is no enigma in the phenomenon, otherwise inexplicable, that these supposed "fissures in the lunar crust" cleave straight through the very ruggedest of mountains and abhor the valleys; for *this is precisely what should be expected of them.* Nor is there any greater marvel in the observed fact that such clefts and the pits of the deeper craters actually delve down deep below the natural level of the surface, thereby adding to the "cavernous" effects. In terrestrial volcanoes the floor of the crater, far from being deeper down than the surrounding regions, is invariably much higher—a most significant distinction.

## GENERAL REFLECTIONS

LUNAR SURFACE CHANGES. The author of all these is, of course, the sun. At midnight on the moon what little air there is should be absolutely dry, all of its moisture having been frozen out of it and deposited upon the surface in the form of frost and snow. On the deepest beds of the sea this coverlet would be but a mere sprinkle, having fallen after the descent of night as the last act in the drama of the day.

Now, on the moon, owing to the exceedingly light atmospheric pressure, water boils at a much lower temperature than here,—let us say, at 32° F., though this can scarcely be more than a close guess. For this reason the thawing process begins *early*—immediately with, or probably an hour before, dawn—so that (as there is no light refraction there) *on the very lowest places such as the maria floors, where it lies at its lightest,* the snow may be effectually flooded over before observers can even glimpse its presence. Granting the reasonableness of this inference, it is easy to understand why areas seen to be just whitening as they pass into the night may at their succeeding dawn appear to have lost their whiteness from some *nocturnal* cause, instead of from the freshets caused by the returning day.

As the sun rises on the lunar landscape, he first shines upon the western sides of the hills; the eastern remaining in shadow, illuminated only by the reflection from the slopes opposite. Wherever his rays impinge, there the process of thawing goes on and the water of thaw naturally flows down the icy slope or seeps down through the porous snow, until it reaches the pool at the bottom. Once there, the water is warmed to a point of boiling (32° F., remember, on the moon), and, rising into the thin atmosphere, is quickly reconverted into snow flurries, which to us look to be clouds of vapor and which selenographers have heretofore been construing as "noxious gases from the moon's volcanic vents."

All this, let it be understood, occurs in the morning of the lunar day. At high noon, the whole bottom of the crater, let us say, is directly open to view, and then the pool ought to appear at its largest and blackest, were it not that just then the snow cloud is probably at its densest. With the passing of the meridian, the eastern wall is now being shone upon by the afternoon sun, and inasmuch as the rays start this time with the vertical instead of with a slant, the eastern melting proceeds much more rapidly at the outset, increasing, say, till 48 hours past noon of the lunar day, and thereafter fading to the minimum at sunset. During this half of the process we see the original pool—now in cold shadow—lose its black aspect and freeze over and whiten with a skim of snow, while, diametrically opposite on the crater floor, another pool forms from the draining of thaw water off the eastern slope, giving off fresh clouds of vapor which, being immediately transformed into flakes, settles wherever it can. I use the word *immediately* advisedly, for Arctic explorers tell us that in those regions the transition of atmospheric vapor into snow is accomplished directly and without the formality of clouds. Commenting on this phenomenon, Prof. W. B. Wright (*The Quaternary Ice Age,* p. 19) says:

> All the explorers who have persisted into the interior (of the Arctic and Antarctic regions) are agreed as to the fine-grained character of the snow which falls there. Among the most interesting of the observations made by Nansen are those bearing on the origin of this snow. He calls attention to the great clearness of the atmosphere during nearly the whole of the time occupied by his journey. On only a few days was the sky overcast, and when snow was falling it was still possible to see the sun. The fine dusty snow appears to be precipitated directly from the lower layers of the atmosphere without the preliminary formation of clouds. It is what is known as *frost snow* in some parts of Norway.

When I use the word "pool", the reader is not to presume that I necessarily mean a *circular* or sub-circular shape. Its shape may indeed be such, but if so, it would be purely accidental. It all depends on the configuration of the *natural* water courses, and these, as everyone knows, may be forked and connected up in any sort of way imaginable. Let a deep lake, for instance, be connected with a distant one by means of a channel, then the appearance at noonday would be that of a dumb-bell crater, with a very black handle connecting the two centers. It so happens in the special case of Aristillus, which Prof. Pickering discusses, that the natural configuration of the crateral basin is such as the dark lines and areas he describes indicate. The basins must possess *some* shape.

There are, however, it appears, some broader changeful areas in the midst of level plains, far distant from the crateral regions, and upon these Prof. Pickering seems to rely most securely for his contention that there is "vegetation on the moon." My own opinion is that these areas, being far remote from the snow producing pools, are covered with horizontal glacial sheets less than a score of feet in thickness, which either become sopped by the midday thaws into a dull slush or, in places *very* far remote from the pools, may even be so thin as to melt away entirely and leave considerable spots wholly bare of icy covering. Obviously, under *my* theory of lunar conditions, vegetation and animal life there are alike out of the question, and candor compels me to add that, even under the volcanic hypothesis of the origin of the moon's features, which Mr. Pickering champions, I cannot see the reasonableness of his view, best qualified of all men though he may be to speak at first hand on this subject.

Why are there no clouds to be seen on the moon, where so much water exists? My answer is, that vapor cannot arise directly from a crystalline surface, but must first pass through the *detached* liquid stage. Until a blanket of snow is reduced to at least the condition of a very shallow slush, it will never give off "steam". On the moon there is indeed an immense amount of thawing going on during the day, but the fluid water, where in immediate contact with crystallic ice, preserves its liquidity and seeps down into and through the porous, spongy snow underneath. Not only this, but such little vapor as *does* form obviously becomes quickly frosted by the "air" and settles immediately. Either of these explanations alone, or at least the two combined, sufficiently suffice to explain the anomaly of the moon's cloudlessness as well as the minor fact that the snow peaks are oftentimes perceptibly whiter than their lower, water-soaked slopes.

ALBEDO. Were the surface of the moon perfectly smooth and covered with new-fallen snow, her albedo (i. e., her general brightness) would far surpass the actuality. The deficiency is due to several things, for instance; first, the strong shadows thrown upon her by her own hills, secondly, the slushiness of certain regions, thirdly, the seaming and corrugating of her snow surfaces due to repeated sopping and irregular settling, and, finally, the darkness of her maria. Paradoxically, *her dark side is intrinsically whiter than her illuminated face,* for then her maria are covered with fresh sprinkles of snow.

ABSENCE OF ATMOSPHERIC REFRACTION. This peculiarity has heretofore very properly been attributed to a paucity of air; some saying that this was carried off by a passing comet; some that it was probably absorbed by porous volcanic rocks; some that it may have been drawn into the moon's interior by causes unknown; some that its lighter molecules escaped into space, and still others that the satellite never had any more atmosphere than it has just now. As the reader has already learned, my own view is, that it has been almost totally absorbed by union with the water in the manufacture of snow crystals.

But there is still another reason. When Prof. Langley invented the bolometer about forty years ago and tested it out on the full moon, he was dumbfounded and disconcerted to find that her heat radiation, instead of being much hotter than at new, is really virtually the same. Nevertheless, he courageously reported the fact as he found it, and was severely ridiculed by no less an authority than the great Proctor himself. Since then, the world of science has been trying to wriggle clear of this evidence; which, however, refuses to down. The sun-lit side of the moon, I reassert, *is intensely cold,* and, being so, the consequent uniformity of her atmospheric temperature from top to bottom greatly diminishes its refractive qualities.

You may wish to ask me why the moon does not rotate, seeing that she was primevally provided with liquid oceans. For this there are two reasons, either one of which would suffice singly. One of these is, that the satellite's gravistatic heat is only a small fraction of the earth's, being in fact only thirty degrees higher at the depth of two miles than it is at, say, 100 feet below her surface. The second reason is, that inasmuch as the lunar oceans could never have exceeded a half mile in depth on the average, and since the weight of water there is only one-sixth of what it has here, the load on the bottom waters could not have been more than fifteen atmospheres and consequently fell far short of the amount requisite to compress them beyond their freezing density.

THE END.

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